ANNOUNCEMENT.

The present Volume completes this Series of Tracts on Physical Science, and its applications. In bringing the Work thus to a close, the purpose of the Author and Publishers has been to confine the collection within such a limit of bulk and price as may be compatible with the leisure and the means of the great majority of its Subscribers. The whole series is now comprised in the moderate limits of twelve single volumes, in ornamental boards, at 18*s*., or six double volumes, in cloth, lettered, at 21*s*.

A desire having been generally expressed that the Series should have been continued, the Publishers state with pleasure that they have made arrangements for the publication of another popular Work for general circulation by the same Author, of which full particulars will be hereafter announced.

This New Series will be commenced as soon as Dr. Lardner has completed some other works which he has undertaken.

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OR, FIRST NOTIONS OF GEOLOGY.

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ERRATA.

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Fig. 2.

THE PRINTING PRESS.

CHAPTER I.

1. The improvement of the art not promoted by men of letters and science.—2. General signification of printing.—3. Printing by models in relief.—4. Method of engraving the block.—5. Antiquity of this art.—6. Invention of movable type.—7. Use of movable types for printing successive books or parts of a book.—8. Process of printing.—9. Composition.—10. Quadrats.—11. Use of the chase.—12. Imposing.—13. Reading and correcting.—14. Successive operations in printing.—15. Inking.—16. Inking-rollers.—17. Stanhope press.—18. Printing-machines.—19. General description of them.—20. Single printing-machines.—21. Double printing-machines.—22. Perspective view and description of Applegath and Cowper's double printing-machine.

1. It is a remarkable fact, that printing, which has so far transcended all other arts in the influence it has exerted in the advancement of knowledge and the progress of the human race, owes almost nothing to the class devoted professionally to letters and the sciences, and on whom it has, nevertheless, bestowed the largest measure of advantage.

2. Printing, in its most general sense, is the name given to all processes in the arts, by which the same forms or characters are indefinitely multiplied, by the impressions of the surface upon which they are formed repeatedly and successively, upon the surface to which they are to be transferred. Thus, in calico-printing, the same figures are transferred in rapid succession to different pieces of cloth, or to different parts of the same piece, by means of blocks or rollers, upon which the figures are produced, either in *relief* or *intaglio*, that is, either in raised or sunken characters. In such cases the blocks, or rollers, are pressed in succession on the surface of the cloth to be printed, being however previously smeared with colouring matter. In the printing of copper or steel engravings, the design is produced by the engraver in lines sunk in the surface of the copper or steel by the engraving tool. These lines being filled with the printing-ink, and all other parts being carefully cleaned, the plate is impressed on the paper with an intense pressure by means of a press specially adapted to that purpose. The paper being previously moistened, absorbs the ink from the lines in which it is deposited, and exhibits after the impression a perfect copy of the engraving,—the sunken lines of the engraving being represented on the paper by corresponding lines in ink.

3. In wood-engravings, and in ordinary book-printing, the original from which the impressions are taken is in relief. A model in relief of the page to be printed is formed in metal called *type-metal*, consisting of lead rendered hard by being alloyed with a small proportion of antimony. The surface being smeared with the colouring-matter called *printing-ink*, is impressed upon the paper, and a *fac-simile* of the original relief is thus produced.

4. In the earliest and rudest attempts at printing, a manuscript page was attached to the surface of a block of wood, which was carved into relief corresponding with the characters of the manuscript. The impression produced by this means was necessarily a *fac-simile*, more or less accurate, of the manuscript itself.

5. The method of printing by means of blocks of wood, or metal, carved in relief, is the earliest example on record of the practical use of the art which, in its more improved state, has exercised so important an influence upon civilisation. According to some antiquarian authorities, the art of producing characters in this way may be traced as far back as the building of Babylon. The characters found upon bricks, taken from the supposed site of that city, having been undoubtedly printed by the method here described. We are in possession of metal stamps, with words engraved in relief, which the Romans made use of to mark their

various articles. If the modern art of making paper had been known in those remote times, it is very probable that the art of printing books would have existed at a much earlier date than that of its actual commencement, for with the same kind of stamps precisely, as those by which the Roman tradesmen marked their wares, books might have been printed, and the same engravings which adorned the shields and pateras of ancient times might, by the aid of paper, have spread the intelligence of Greece and Italy over the world.

According to Du Halde and certain missionaries, the art of printing from blocks carved in relief was practised in China fifty years before the Christian era; and, from the early commercial intercourse of the Venetians with that country, there is reason to believe that the knowledge of this art, in its application to the multiplying of books, was originally derived from thence, for Venice is the first place in Europe in which it is recorded to have been practised.

Its first application was to the production of playing cards and religious prints, and when the art was first extended to books they were printed by carving each page upon a separate block. This process of carving the characters in relief, which was probably executed by attaching the manuscript to the face of the block and engraving from the manuscript, will afford an easy and obvious explanation of the diversity of characters found in ancient books printed from such blocks, and will explain the great similarity which exists between books thus printed and manuscripts. This similarity was increased by their being printed on one side of the paper only, the indentation produced by the impression being removed by burnishing the back. Two leaves were then pasted together, making such a perfect *fac-simile* of the manuscript, as to require, even at the present day, great discrimination and much chemical skill to distinguish such books from real manuscripts; and as they have no printers' names, dates, or places affixed to them, it is impossible to ascertain by whom, or when, or where they were executed. The fabrication of these pseudo-manuscripts involved the first introduction of the art of printing.

6. **Movable Types.**—About the middle of the fifteenth century the art of printing in this rude manner acquired considerable extension; but as each separate work required to have separate blocks for each page, and since the blocks for one work were altogether useless for another, the printers soon began to feel the inconvenience arising from the storage of such numerous collections of blocks, to say nothing of the expense of carving them. They were, therefore, stimulated to seek for some method less costly and cumbrous, by which the models in relief of the pages could be

produced, and so that the materials of the model of any one page might be afterwards useful, in the formation of the models of other pages. The discovery of the means of accomplishing this object by movable types constitutes the most important epoch in the history of printing, and is sometimes even regarded, in all essential respects, as the invention of printing itself. After it had undergone some successive improvements, it resolved itself into the production of models in relief of the letters of the alphabet, formed upon the extremities of small bars of metal, which being properly selected and placed in juxtaposition, formed the words and letters of a page. Such are the *types* of the modern printer.

The honour of the invention of movable types has been disputed by two cities, Haarlem and Mentz. The claims of Haarlem rest chiefly upon a statement of Hadrien Junius, who gave it upon the testimony of Cornelius, alleged to be a servant of Lawrence Coster, for whom the invention is claimed. The claims of Mentz, which appear to be more conclusive, are in favour of Peter Schæffer, the assistant and son-in-law of John Faust, better known as Dr. Faustus. The first edition of the *Speculum humanæ salvationis* was printed by Coster at Haarlem, about the year 1440, and is one of the earliest productions of the press of which the printer is known. The celebrated Bible, commonly known as the Mentz Bible, without date, is the first important specimen of printing with movable metal types. This was executed by Gutenberg and Faust, or Fust, as it is sometimes spelt, between the years 1450 and 1455. The secret of the method then becoming known, presses were speedily established in all parts of Europe, so that before the year 1500 there were printing-offices in upwards of 220 different places in Austria, Bavaria, Bohemia, Calabria, the Cremonese, Denmark, England, Flanders, France, Franconia, Frioul, Geneva, Genoa, Germany, Holland, Hungary, Italy, Lombardy, Mecklenberg, Moravia, Naples, the Palatinate, Piedmont, Poland, Portugal, Rome, Sardinia, Upper and Lower Saxony, Sicily, Silesia, Spain, Suabia, Switzerland, Thessalonica, Turkey, Tuscany, the Tyrol, Venice, Verona, Westphalia, Wurtemberg, &c.

This vast and rapid extension of the art, combined with the skill which the earlier printers displayed in it, seems to be totally incompatible with the date assigned to the invention, and it is more probable, that the art having been long practised in private under continued attempts at secrecy, it at length broke into publicity after it had already attained a considerable degree of perfection.

7. When the page of a book is formed by properly combining

the types, and a sufficient number of copies of it produced by the process of printing, the types which form it are disengaged and separated and used to form other pages of the same or other books. Thus, while in the first attempts at printing, each model of letter in relief never did any other duty than the printing of the very book for which it was formed, the type of each letter in printing with movable types is transferred from page to page, and is used successively in the printing of an indefinite number of pages of the same or different works.

8. **The process of printing,** then, consists in a certain succession of operations, the first of which is putting together the types so as to form lines and pages; the second, putting together these pages in such a manner, that when impressed upon sheets, and the sheets folded, they will succeed each other in the proper order. The subsequent operations of folding, stitching, and combining these sheets together, so as to form a volume, is the business of the bookbinder.

9. **Composition.**—The process of putting the types together is called *composing*, and the person who performs this operation is called a *compositor*. He stands before an inclined desk, as shown in the view of the composing-room (fig. 1), which is divided into a number of compartments of different sizes, A, B, in each of which are placed a certain number of types of a particular letter. By practice he learns without hesitation to direct his hand to the compartment which contains the letter he wants, without removing his eye from the manuscript which lies before him. He holds in his left hand an instrument called a *composing-stick*, which is so formed as to receive the types in successive juxtaposition, until the requisite number have been placed to form a complete line, after which another line is composed in like manner, and thus line after line is composed until a complete page has been formed. The spaces between words are made by the insertion of small bars called *quadrats*, similar to those of type, but having no letter cast upon their ends, and the spaces between line and line are produced by the insertion of thin plates of metal called *leads*. When the lines are considerably separated from one another, they are accordingly said to be "leaded." When a page has been composed the compositor ties a cord round it, called a *page-cord*, to hold the types of which it consists provisionally together, and placing it apart, proceeds to form another page, and so on.

10. Since every line of the same page must necessarily have the same length, whether the types which compose it fill out that length or not, any deficient space is filled by quadrats placed at the most convenient points between the words.

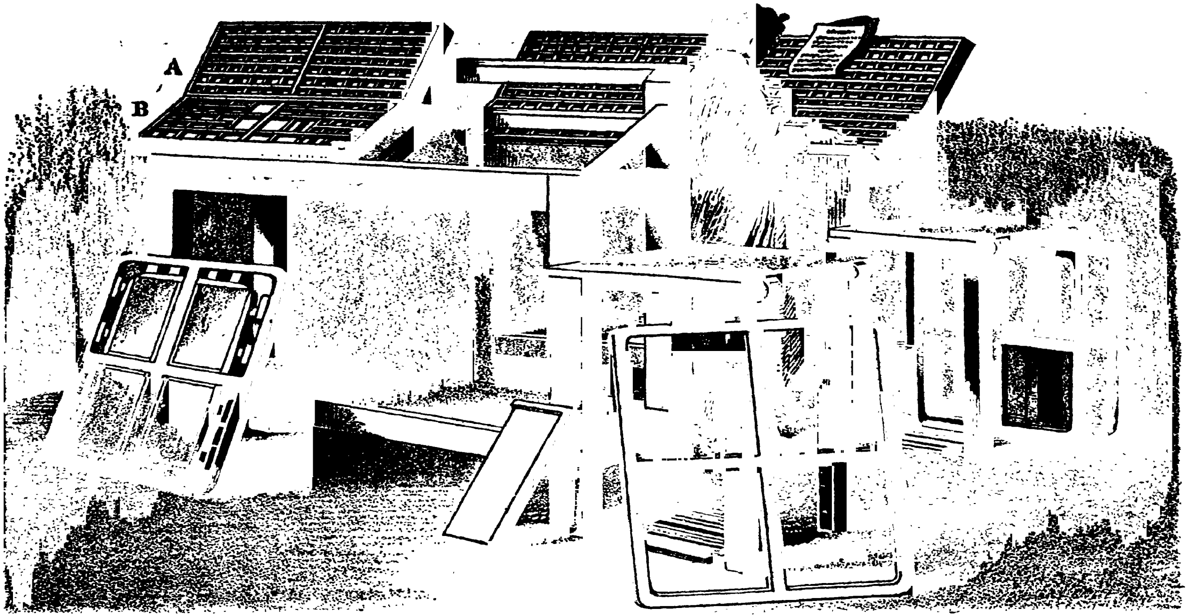


Fig. 1.—Composing Room.

In like manner the blank parts of last lines of paragraphs are filled with quadrats.

11. When the pages of one side of a sheet have been thus composed, they are placed in the divisions of an iron form called a *chase*, C, D, several of which appear in the view of the composing-room, fig. 1. These chases, of course, vary in their form and mode of division according to the size and number of the pages which form a sheet. We have here supposed the pages which are composed and arranged in the chase to be those which are required to be printed on one side of the sheet. A similar number are composed and similarly put together in another chase, being those to be printed on the other side of the sheet.

12. **Imposing.**—The process of arranging the pages in the chase is called "imposing."

13. **Readers and Correctors.**—When the pages composing each side of the same sheet have been thus "*imposed*," and the types securely fastened in the chase by proper wedges, the chases are brought to a printing-press, which will be presently described, where a single impression is taken from them, called the *first proof*, which, being properly folded, is taken to a person called the "*reader*," who has always a boy capable of reading the manuscript to assist him. While the boy reads the manuscript, the "*reader*" follows him upon the proof, which he carefully examines, and upon which he marks the errors of the compositor. The proof is then returned to the compositor, who corrects the errors indicated by the reader, and a second impression is then taken with more care, and generally on better paper. This is called a *clean proof*, and is again examined by the reader to ascertain whether the compositor has corrected all the errors previously indicated; and if there are none uncorrected, the proof is then sent to the author. In good printing-offices there are few or no press errors found in the author's proof, those corrected by him being in general errors which had been overlooked in his own manuscript, or corrections of language suggested to him in the revision of the sheet.

14. After the sheet has received the correction of the author, the form to be printed is laid upon a horizontal table, with the faces of the types uppermost, and the following operations are executed:—1st. Printing-ink is applied to the faces of the type, so evenly that there shall be no blotting or inequalities in the printing; 2nd. The sheet of paper to be printed is laid upon the form so as to receive the impression of the type in its proper position, and in the centre of it; 3rd. This paper is urged upon the type by a sufficient pressure to enable it to receive the printed characters, such pressure, however, not being so great as to cause

the type to penetrate or deface the paper; 4th. The paper is, in fine, when thus printed, withdrawn from the type and laid upon a table, where the printed sheets are collected.

15. **Inking.**—In the old process these operations were performed by two men, one of whom was employed to ink the types, and the other to print. The former was armed with two bulky inking-balls, consisting of a soft black substance of leathery appearance, spherical form, and about twelve inches in diameter. He flourished these with dexterity, dabbed them upon a plate smeared with ink, and then with both hands applied them to the faces of the types until the latter were completely charged with ink. This accomplished, the other functionary—the pressman—having prepared the sheet of paper while the type was being inked, turned it down upon the type, drew it under the press, and with a severe pull of the lever gave the necessary pressure by which the paper took the impression of the type. A contrary motion of the apparatus withdrew the type from under the press, and the pressman, removing the paper now printed, deposited it upon a table placed near him to receive it. The same series of operations was then repeated for producing the impression of another sheet and so on. In this manner two men in ordinary book-work usually printed at the rate of 250 sheets per hour on one side.

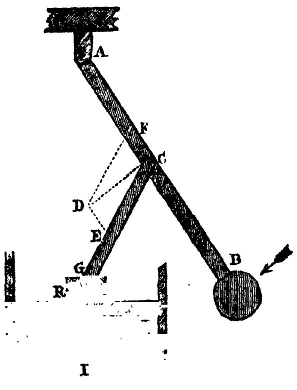
16. **Inking-rollers.**—One of the first improvements which took place upon this apparatus consisted in the substitution of a cylindrical roller for the inking-balls. This roller was mounted with handles, so that the man employed to ink the type first rolled it upon a flat surface smeared with ink (fig. 2), and having thus charged it, applied it to the type form, upon which he rolled it in a similar manner, thus transferring the ink from the roller to the faces of the type. The substitution of these inking-rollers for the inking-balls constituted one of the most important steps in the modern improvement of the art of printing. The rollers were composed of a combination of treacle and glue, and closely resembled caoutchouc in their appearance and qualities.

17. **Stanhope Press.**—The process by which these operations were executed, assumed in the course of years a great variety of improved forms, and one of the most celebrated and most universally adopted having been supplied by the inventive genius of Earl Stanhope, has accordingly retained his name, and is known as the *Stanhope press.* This machine, which, resembling all other improved presses in its general features, and serving, therefore, as an example of hand-presses in general, is shown in fig. 3. The two principal parts of the machine are *first,* that which produces the pressure, and the *second,* that which supports the paper. The former is a massive frame of cast iron, formed in a single

Fig. 3.—Stanhope Press.

piece, in the upper part of which is a nut, in which a screw moves—the point of which acts upon the upper end of a slider, which is fixed into a dovetailed groove formed between two vertical bars of the frame. This slider has attached to its lower end a square plate, called the *platten*, which rises and falls according as the screw is turned in the one direction or the other. The weight of the platten fig. 3, A, and slider, which is considerable, is counterpoised by a heavy weight C suspended by a lever behind the press. The flat table, called the *carriage*, upon which the form of types is laid, is moved backwards and forwards by means of a winch, which appears in fig. 3. By means of this winch, and the rack or band with which it is connected, the carriage with the type form can be moved by the pressman alternately backwards and forwards, so that it can be brought under the platten, and after having received the pressure, can be removed back to its first position. The platten is made to impart the pressure by means of a lever called the *knee lever*, an expedient which is much used in the arts in cases where any intense pressure is required to be produced through a very limited space. The mechanical effect of this species of lever will be understood by a reference to fig. 4, where A B is a metal rod, having a fixed point of support A on which it works; another bar G C is jointed to it at C, a point intermediate between A and B. This bar C G is jointed at G to a plate such as R, or any other object to which it is desired to transmit any intense force acting through a very limited space, as, for example, in the present case, where the paper is pressed upon the type by a plate which is driven upon it by a sudden and severe force. The handle B of the lever being pressed in the direction of the arrow, exerts a corresponding pressure on the point C, which is driven in the direction C D perpendicular to A B. This motion C D is resolved into two by the parallelogram of forces, one in the direction C E, and the other in the direction C F; the latter exerts pressure on the fixed point A, and the other acts upon the plate R by means of the joint G forcing it downwards. As the joint C advances, the angle A C G becomes more and more obtuse, and the component C E

Fig. 4.



of the force acting at B, bears a rapidly increasing proportion to the force itself, so that when the levers A C and C G come nearly into a right line, the pressure exerted at B is augmented at G in an almost infinite proportion.

In working the press, the pressman places a sheet of paper to be printed upon the frame F, called the *tympan*, where it is held in its place by turning over it the frame G, which is supplied with rods or cords corresponding to the spaces between the pages of the form. While the pressman is thus employed, his assistant is engaged in inking the types with a roller, as shown in fig. 3. When this has been accomplished, the pressman turns down the tympan carrying the paper upon the types, and then, by turning the handle, moves the carriage with the type form upon it under the platten, and applying his hand to the handle above him presses the platten down upon the tympan carrying the paper, and by means of the knee lever produces a sudden and severe pressure by which the paper receives the impression of the type. The handle is then moved in a contrary direction, the platten being raised from the type form, and by turning the other handle the carriage with the type form is removed from under the platten. The pressman then raises the tympan from the types, and taking the printed sheet off, replaces it by a fresh blank sheet, over which he turns the frame as before; and while he is performing this operation, his assistant is occupied in inking the types, after which the same operations are performed, and another sheet is printed, and so on.

18. **Printing Machines.**—The printing presses which served the purposes of publication for some hundred years, during which they received no other improvements than such as might be regarded merely as modifications in the detail of their mechanism, have been almost entirely superseded by engines of vastly increased power and improved principles of construction. Although these admirable machines differ one from another in the details of their mechanism, according to the circumstances under which they are applied, and the power they are expected to exert, they are nevertheless characterised by certain common features.

19. The form to be printed is laid in the usual manner upon a perfectly horizontal table, with the faces of the types uppermost; and upon the same table, in juxtaposition with the form, and level with the faces of the types, or nearly so, is placed a slab upon which a thin and perfectly regular stratum of printing-ink is diffused; the table thus carrying the form and inking-slab is moved by proper machinery right and left horizontally, with a reciprocating rectilinear motion through a space a little greater than the length of the form.

Above the form and slab are mounted, also in juxtaposition, a large cylinder or drum, which carries upon it the sheet of paper to be printed, and three or four inking-rollers similar to that already described. There are also three or four other rollers in juxtaposition with the latter, one of which supplies ink to the others, which severally spread it in a uniform stratum upon the slab. The paper-cylinder and the inking and diffusing rollers are so mounted, that when the horizontal table, carrying the form and inking slab, moves alternately backwards and forwards under them, they roll upon it.

In this way, when the table is moved towards the rollers, the form, passing under the inking-rollers right and left, receives from them the ink upon the face of the type; and at the same time the slab, moving backwards and forwards under the diffusing rollers, receives from them, upon its surface, the proper stratum of ink to supply the place of that which was taken from it by the inking-rollers.

20. **Single Printing Machines.**—When the table is moved alternately towards the other side, the form, with the types already inked, passes under the cylinder carrying the paper, the motion of which is so regulated as to correspond exactly with the rectilinear motion of the table carrying the form. The cylinder is urged upon the type with a regulated force, sufficient and not more than sufficient, to impress the type upon the paper.

The sheets of paper are supplied in succession to the cylinder, and held evenly upon it by bands of tape while they pass in contact with the type. After receiving the impression of the type, the tapes which bound them are separated, and the printed sheets discharged.

Such is the general principle of single printing-machines.

21. **Double Printing Machines.**—In these the table which is moved alternately right and left, carries two forms, one corresponding to the pages to be printed on one side of the sheet, and the other to those to be printed on the other side. There are also two inking-slabs, one to the left of the left-hand form, and the other to the right of the right-hand form. There are also two paper cylinders, and two sets of inking and diffusing-rollers. Each sheet of paper to be printed, being held between tapes, as already described, is carried successively round the two cylinders, being so conducted, in passing from one to the other, that one side of it passes in contact with, and is printed by, one form, and the opposite side by the other form. The proportion of the motions is so nicely regulated, that the impression of each page or column made on one side of the paper, corresponds exactly with that of the corresponding page or column on the other side.

This general description will be more clearly understood by reference to the following illustrative diagrams :—

Fig. 5 illustrates the operation of a single printing-machine. The form A and the inking-slab B, are placed on a horizontal table ; above them is the paper-cylinder D, the inking-rollers *i i i*, the diffusing-rollers *c c*, and the rollers C, which supply the ink to the diffusing-rollers. The first of these, C, is called the ductor roller. When the table X Y is moved towards the left, from Y to X, the form A passes under the inking-rollers *i i i*, and receives ink from them on the faces of the type ; at the same time the slab B passes under the diffusing-rollers *c c*, and receives from them a supply of ink to replace what it has just given to the inking-rollers.

Fig. 5.

When the table is moved in the contrary direction, from X towards Y, the form once more passes under the inking-rollers, and afterwards under the paper-cylinder, which being pressed upon it, while it moves in exact accordance with it, the types discharge upon the paper the ink they have just received from the rollers ; and the printing of the paper being thus effected on one side, the sheet is discharged from the tapes. The table is then again moved to the left, and the types are again inked, and the same effects ensue as have already been described.

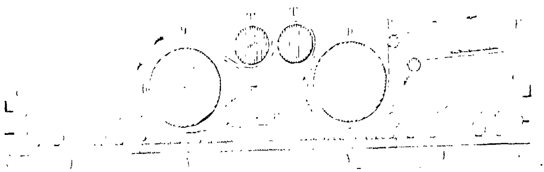
In this manner sheet after sheet is printed.

The inking and diffusing-rollers rest upon the slab and types by their weight, the axes projecting from their ends being inserted in slits formed in upright supports, attached to opposite sides of the frame which supports the moving table. The two upright pieces in which the axes of each roller are inserted, are not placed in exact opposition to each other ; the consequence of which is, that the rollers are placed with their axes slightly inclined to the sides of the table. This arrangement is attended with a very important effect : for, in consequence of the friction or adhesion of the rollers with the slab, they are moved alternately in contrary directions with the longitudinal motion across the table. This motion, combined with their rolling motion upon the

slab, aids materially in diffusing the ink in a perfectly uniform stratum.

An illustrative diagram of a double printing-machine is shown in fig. 6, where D and D′ are the two paper-cylinders; A and A′, the two forms; *i i i* and *i′ i′ i′*, the inking-rollers; *c c* and *c′ c′*, the diffusing-rollers; and C and C′ the ductor-rollers. The pile of paper placed on the table E, is

Fig. 6.



supplied sheet by sheet to the tapes between which it is held; and being passed over the roller R, and under the cylinder D′, it receives the impression of the types of the form A′; it then passes successively over the roller T′, under T, and round the cylinder D, at the lower point of which its unprinted side comes into contact with the types of the form A, by which it is printed; after which, the tapes opening, it is thrown out by the centrifugal force upon the receiving table F.

It will be apparent by the figure, that while the sheet is printed on one side by the form A′, the form A is passing between the inking-rollers *i i i*, and the slab B; and on the contrary, while the paper is printed on the other side by the form A, the form A′ is passing between the inking-rollers *i′ i′ i′* and the slab B′.

In this manner, by each alternate motion from right to left, and from left to right, a sheet is printed on both sides.

22. A perspective view of a double-acting printing machine, as constructed by Messrs. Applegath and Cowper, is shown in fig. 7.

A boy, called the *layer-on*, E, standing at an elevated desk, pushes the paper, sheet by sheet, towards the tapes, which, closing upon it, carry it over a roller R, passing under which it is carried to the right of the cylinder D, under which it passes, and being carried up to the left of it, passes successively over the roller T, under the roller T′, over the cylinder D, and drawn along its left side, after which it passes under it, and is flung into the hands of a boy, F, called the *taker-off*, seated before a table placed between the two cylinders D and D′, upon which he disposes the sheets as he receives them.

In this manner the layer-on feeds the machine in constant succession with blank sheets, which, being carried under the cylinder D, are printed on one side, and afterwards under the cylinder D′, are printed on the other, when they are received by the taker-off.

APPLEGATH AND COWPER'S MACHINE.

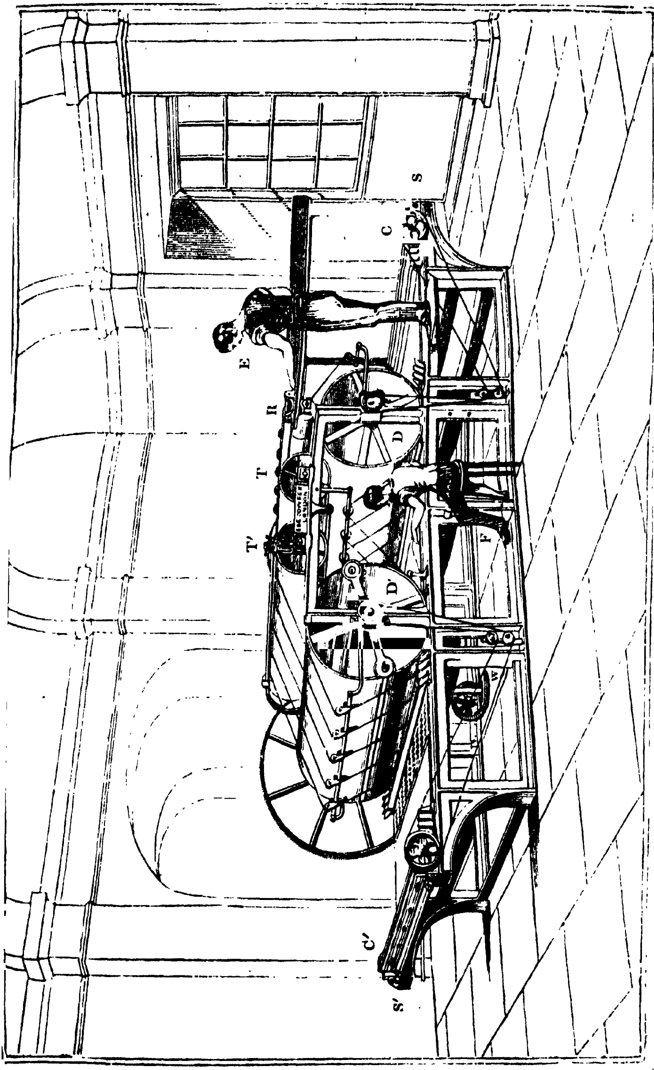


Fig. 7.—Applegath and Cowper's Double Printing Machine

The ductor-rollers, C and C′, are kept in revolution by endless bands, carried over rollers at the lower parts of the frame, and then over grooved wheels fixed on the axes of the cylinders. The table carrying the forms and slabs is moved alternately right and left by means of a pair of bevelled wheels, W, under the frame, and a double rack and pinion above; one of the bevelled wheels, having a horizontal axis, receives motion from a steam-engine or other moving power; it imparts motion to the other bevelled wheel, having a vertical axis. This latter axis has a pinion fixed at its upper end, which works in a double rack attached to the movable type-table, which is so constructed that the continuous rotation of the pinion imparts an alternate rectilinear motion right and left to the rack and to the table attached to it.

The manner in which the tapes lay hold of and conduct the paper successively round the cylinders, and finally discharge it upon the table of the taker-off, will be easily understood by reference to fig. 8, page 177.

C and D are two grooved rollers, surrounded by an endless band which pushes the paper from the table of the layer on towards the tapes. The two endless tapes, between which the paper is held, are represented in the diagram by the continuous and dotted lines, and the direction of their motion round the rollers and cylinders is represented by the arrows. It will be perceived that opposite the table of the layer-on, the tapes converge, from two small rollers *d* and *h*, and come into contact at the top of the roller E. The edges of the sheets of paper, being advanced from the table of the layer-on, are caught between the tapes immediately above the roller E.

It must be understood that there are two or three pairs of tapes parallel to each other, which correspond to the margins of the pages or columns; but only one pair is shown in the figure.

The paper being thus seized between the tapes above the roller E, is carried successively, as shown in the figure, still held between the tapes, under and over F H I and G, until it arrives at *i*, where the tapes separate, that which is indicated by the continuous line being carried to the roller *a*, and that by the dotted line, over the roller *i*, to the roller *k*. The tapes being thus separated the printed sheet is discharged at *i*, upon the table of the taker-off; meanwhile, the tape indicated by the continuous line is carried successively over the roller *a*, under *b*, under *c*, outside *d*, and is finally returned to the roller E.

In the same manner the tape indicated by the dotted line is carried successively under the roller *k* and *m*, outside *n*, over *v* and *h*, from which it returns to E, where it again joins the other tape proceeding from *d*.

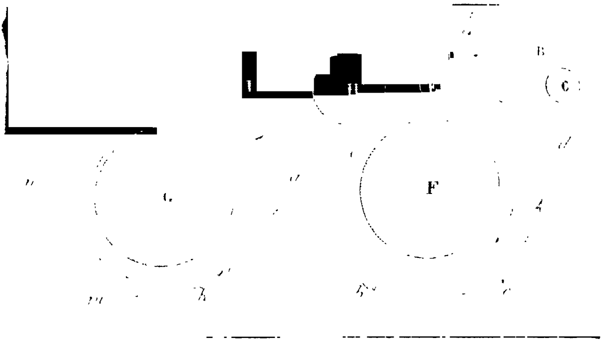


Fig 8.

THE PRINTING PRESS.

CHAPTER II.

23. Machine of *The Times* of 1814. — 24. Improvement of this. — 25. Present printing machine of *The Times*. — 26. Marinoni's newspaper printing machine.—27. Marinoni's book-printing machine.—28. Newspapers.—29. Reporters.—30. Court newsman.—31. Foreign correspondent.—32. Newspaper statistics.

23. THE first machines constructed upon this improved principle for printing newspapers, were erected at the printing office of *The Times* newspaper, and it was announced in that journal, on the 28th of November, 1814, that the sheet which was then placed in the hands of the reader, was the first printed by steam-impelled machinery.

By this, with some improvements which the apparatus received soon afterwards, the effective power of the printing-press was augmented in a very high proportion. With the hand-presses previously in use, not more, as we have seen, than 250 sheets could be printed on one side in an hour. Each of the two machines erected at *The Times* office produced 1800 impressions per hour.

24. **Further Improvement.**—The power of the printing-machine constructed upon this principle was soon after augmented, by increasing the number of printing-cylinders to

four, the principle of the machine, however, remaining the same.

The manner in which this was accomplished will be easily understood by the aid of the illustrative diagram, fig. 9, where 1, 2, 3, and 4, are the printing-cylinders: P P P′ P′, are the tables of the four layers-on, and O O O′ O′, lead to those of the four takers-off. The course followed by the sheets of paper, in passing to and from the cylinders, are indicated by the arrows. Inking rollers are in this case placed at R, between the printing-cylinders; the two type-forms are inked twice, while they move from right to left, and twice again while they move from left to right. *The printing-cylinders are alternately let down upon the type and raised from them in pairs; while the type-table moves from left to right, the cylinders 1 and 3 are in contact with the table, the cylinders 2 and 4 being raised from it, and, on the contrary,* when it moves from right to left, the cylinders 2 and 4 are in contact with it, 1 and 3 being raised from it.

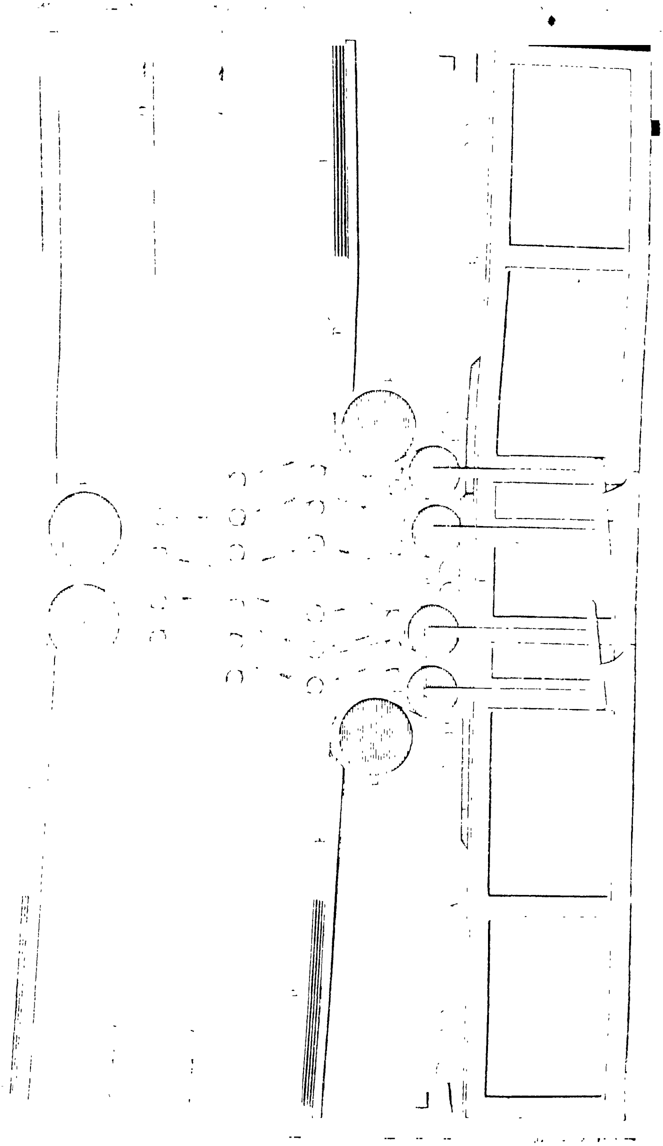
By this improvement, which was adopted in *The Times* office in 1827, the proprietors of that journal obtained the power, then unprecedented, of printing from 4000 to 5000 sheets per hour on one side of the paper. By this means they were enabled to satisfy the demands of a circulation amounting to 28000.

In reference to newspaper-printing, it must be here observed that the great object to be attained, is to increase the celerity by which printing on one side only of the sheet can be augmented. It is found convenient so to arrange the letter-press that the matter appropriated to one side of the sheet shall be ready for press at an early hour, and may be printed before the contents of the other side, in which the most recent intelligence is included, can be prepared. Hence the advantage of using machines adapted to print one side only with the most extreme celerity for newspapers.

25. **"Times" Printing-machine.**—This machine continued to serve the purposes of *The Times* newspaper until a later epoch, when again the exigencies of the press exceeded even its immense powers, and another appeal was made to the inventive genius of Mr. Applegath. It was, in short, necessary to provide a machine by which at least 10000 sheets an hour could be worked off from a single form!

In considering the means of solving this problem, it is necessary to observe, that whatever expedient may be used, the sheets of paper to be printed must be delivered one by one to the machine by an attendant. After they once enter the machine they are carried through it and printed by self-acting machinery. But in the case of sheets so large as those of the newspapers, it is

Fig. 9.



found that they cannot be delivered with the necessary precision by manipulation at a more rapid rate than two in five seconds, or twenty-five per minute, being at the rate of 1500 sheets per hour. Now, in this manner, to print at the rate of 10000 per hour, would require seven cylinders, to place which so as to be acted upon by a type-form moving alternately in a horizontal frame, in the manner already described, would present insurmountable difficulties.

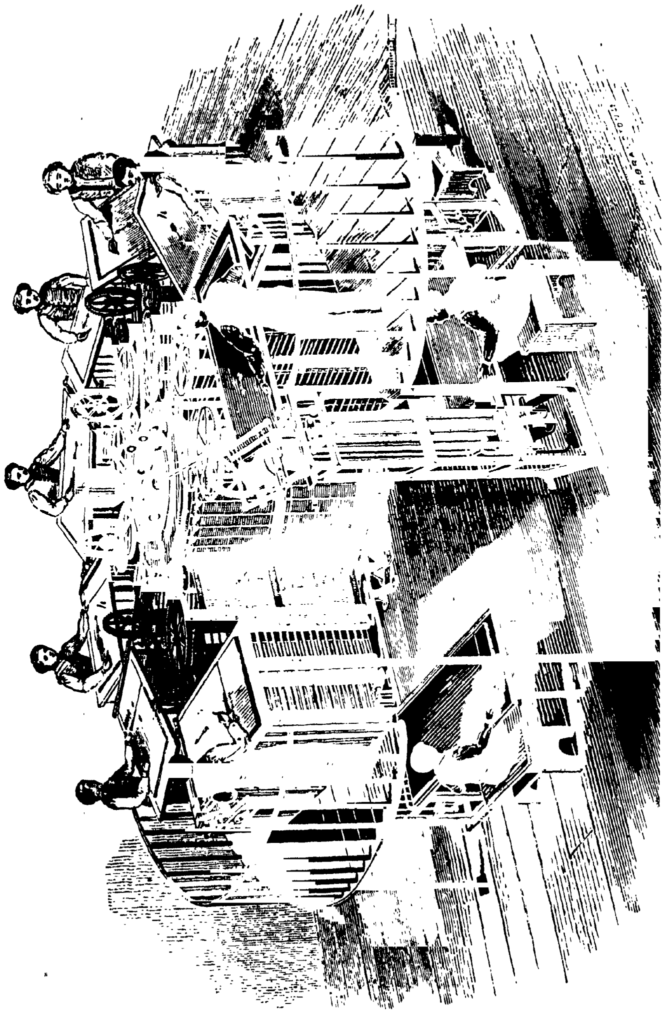
In the face of these difficulties, Mr. Applegath, to whom the world is indebted for the invention of *The Times* printing-machine, decided on abandoning the reciprocating motion of the type-form, arranging the apparatus so as to render the motion continuous. This necessarily involved circular motion, and accordingly he resolved upon attaching the columns of type to the sides of a large drum or cylinder, placed with its axis vertical, instead of the horizontal frame which had been hitherto used. A large central drum is erected, capable of being turned round its axis. Upon the sides of this drum are placed vertically the columns of type. These columns, strictly speaking, form the sides of a polygon, the centre of which coincides with the axis of the drum, but the breadth of the columns is so small compared with the diameter of the drum, that their surfaces depart very little from the regular cylindrical form. On another part of this drum is fixed the inking-table. The circumference of this drum in *The Times* printing-machine measures 200 inches, and it is consequently 64 inches in diameter.

The general form and arrangement of the machine are represented in fig. 10, where D is the great central drum which carries the type and inking tables.

This drum in *The Times* machine is surrounded by eight cylinders, E, E, &c., also placed with their axes vertical, upon which the paper is carried by tapes in the usual manner. Each of these cylinders is connected with the drum by toothed-wheels, in such a manner that their surfaces respectively must necessarily move at exactly the same velocity as the surface of the drum. And if we imagine the drum, thus in contact with these eight cylinders, to be put in motion, and to make a complete revolution, the type-form will be pressed successively against each of the eight cylinders, and if the type were previously inked, and each of the eight cylinders supplied with paper, eight sheets of paper would be printed in one revolution of the drum.

It remains, therefore, to explain, first, how the type is eight times inked in each revolution; and, secondly, how each of the eight cylinders is supplied with paper to receive their impression.

Beside the eight paper-cylinders are placed eight sets of inking rollers; near these are placed two ductor rollers. These ductor rollers receive a coating of ink from reservoirs placed above



them. As the inking-table attached to the revolving drum passes each of these ductor-rollers, it receives from them a coating of ink. It next encounters the inking rollers, to which it delivers over this coating. The types next, by the continued revolution of the drum, encounter these inking rollers, and receive from them a coating of ink, after which they meet the paper-cylinders, upon which they are impressed, and the printing is completed.

Thus in a single revolution of the great central drum the inking-table receives a supply eight times successively from the ductor-rollers, and delivers over that supply eight times successively to the inking rollers, which, in their turn, deliver it eight times successively to the faces of the type, from which it is conveyed finally to the eight sheets of paper held upon the eight cylinders by the tapes.

Let us now explain how the eight cylinders are supplied with paper. Over each of them is erected a sloping desk, *h*, *h*, &c., upon which a stock of unprinted paper is deposited. Beside this desk stands the layer-on, who pushes forward the paper, sheet by sheet, towards the tapes.

These tapes, seizing upon it, first draw it down in a vertical direction between tapes in the eight vertical frames, until its edges correspond with the position of the form of type on the printing-cylinder. Arrived at this position, its downward motion is stopped by a self-acting apparatus provided in the machine, and it is then impelled by vertical rollers towards the printing cylinder, these rollers having upon them marginal tapes which carry the paper round the cylinder, from which it receives the impression of the types. After this the central and lower marginal tapes dismiss the sheet of paper, which the upper ones only become charged with, and carry it to its proper place, where the tapes are stopped with the paper suspended between them, until the taker-off draws the sheets down, ranging them upon his table. These movements are continually repeated; the moment that one sheet passes from the hands of the layer-on, he supplies another, and in this manner he delivers to the machine at the average rate of two sheets every five seconds; and the same delivery taking place at each of the eight cylinders, there are sixteen sheets delivered and printed every five seconds.

It is found that by this machine in ordinary work between 10000 and 11000 per hour can be printed; but with very expert men to deliver the sheets, a still greater speed can be attained. Indeed the velocity is limited, not by any conditions affecting the machine, but by the power of the men to deliver the sheets to it.

In case of any misdelivery a sheet is spoilt, and, consequently, the effective performance of the machine is impaired. If, however, a still greater speed of printing were required, the same description of machine, without changing its principle, would be sufficient for the exigency; it would be necessary that the types should be surrounded with a greater number of printing cylinders.

It may be right to observe, that the cylinders and rollers are not uniformly distributed round the great central drum; they are so arranged as to leave on one side of that drum an open space equal to the width of the type form. This is necessary in order to give access to the type form so as to adjust it.

One of the practical difficulties which Mr. Applegath had to encounter in the solution of the problem, which he has so successfully effected, arose from the shock produced to the machinery by reversing the motion of the horizontal frame, which, in the old machine, carried the type-form and inking-table, a moving mass which weighed twenty-five hundred weight. This frame had a motion of 88 inches in each direction, and it was found that such a weight could not be driven through such a space with safety, at a greater rate than about forty-five strokes per minute, which limited its *maximum* producing power to 5000 sheets per hour.

Another difficulty in the construction of this vast piece of machinery was so to regulate the self-acting mechanism that the impression of the type-form should always be made in the centre of the page, and so that the space upon the paper occupied by the printed matter on one side may coincide exactly with that occupied by the printed matter on the other side.

The type-form fixed on the central drum moves at the rate of about 80 inches per second, and the paper is moved in contact with it of course at exactly the same rate. Now, if by any error in the delivery or motion of a sheet of paper, it arrive at the printing-cylinder 1-80th part of a second too soon or too late, the relative position of the columns will vary by 1-80th part of 80 inches—that is to say, by one inch. In that case the edge of the printed matter on one side would be an inch nearer to the edge of the paper than on the other side.

This is an incident which rarely happens, but when it does, a sheet, of course, is spoilt. In fact, the waste from that cause is considerably less in the present vertical machine than in the former less powerful horizontal one.

The vertical position of the inking-rollers, in which the type is only touched on its extreme surface, is more conducive to the goodness of the work than the horizontal machine, where the

inking-rollers act by gravity; also any dust shaken out of the paper, which formerly was deposited upon the inking-rollers, now falls upon the floor.

With this machine 50000 impressions have been taken without stopping to brush the form or table.

26. **Marinoni's Newspaper Printing-press.**—Messrs. Marinoni and Co., of Paris, have, within the last few years, constructed improved printing presses for newspapers of large circulation, several of which have been erected and brought into operation in the printing-office of the Paris journal *La Presse*. This printing-machine, which is capable of working off 6000 copies per hour, printed on both sides of the paper, is represented in fig. 11. It will be perceived that eight men are employed in the process, four layers-on and four takers-off. The machine is double, the parts at each side of a vertical line drawn through the axis of the fly-wheel being perfectly similar. The manner in which the sheets pass to and from the printing-rollers will be more readily understood by fig. 12, where A is the upper and A′ the lower delivering-board, and B the upper and B′ the lower receiving-board on the right, the two delivering and receiving-boards on the left being similarly placed. The motion of the sheets, as they are conducted to and from the rollers by the tapes, is indicated by arrows, and the course followed by each sheet from the moment it leaves the delivering-board until it arrives at the receiving-board, is indicated by the numbers 1, 2, 3, 4, &c. Thus, the sheet delivered from the board A is taken by the tapes which pass round the roller M, and carried from 1 to 2. Arriving at the lower roller, it passes, as shown by the arrow, between the rollers, 3, and is carried from 4 under the printing-roller I, where it is printed on one side, after which it is carried up between the tapes to 5, from whence it is discharged between the tapes of 6, and carried up over the roller R at 7, from which it is carried down between the tapes 8, and thrown, as shown by the arrow, to the tapes 9, by which it is again carried under the roller and printed on the other side; after which it is carried up successively between the tapes 10 and 11 to 12, and finally discharged from 13 at 14 upon the receiving-board B.

The sheet delivered from the lower receiving-board A′, follows a course precisely similar, entering at 1′ and passing round the printing-roller at 2′ 3′, from which it passes between the tapes 4′ round the roller R′ at 5′ 6′, and thence from the tapes 7′ 8′ round the printing-roller I′ at 9′, by which it is printed on the other side; after which it is carried by 10′, 11′, 12′ to the lower receiving-board B′ at 13′.

The inking-rollers are shown at E P D and D′, and are arranged

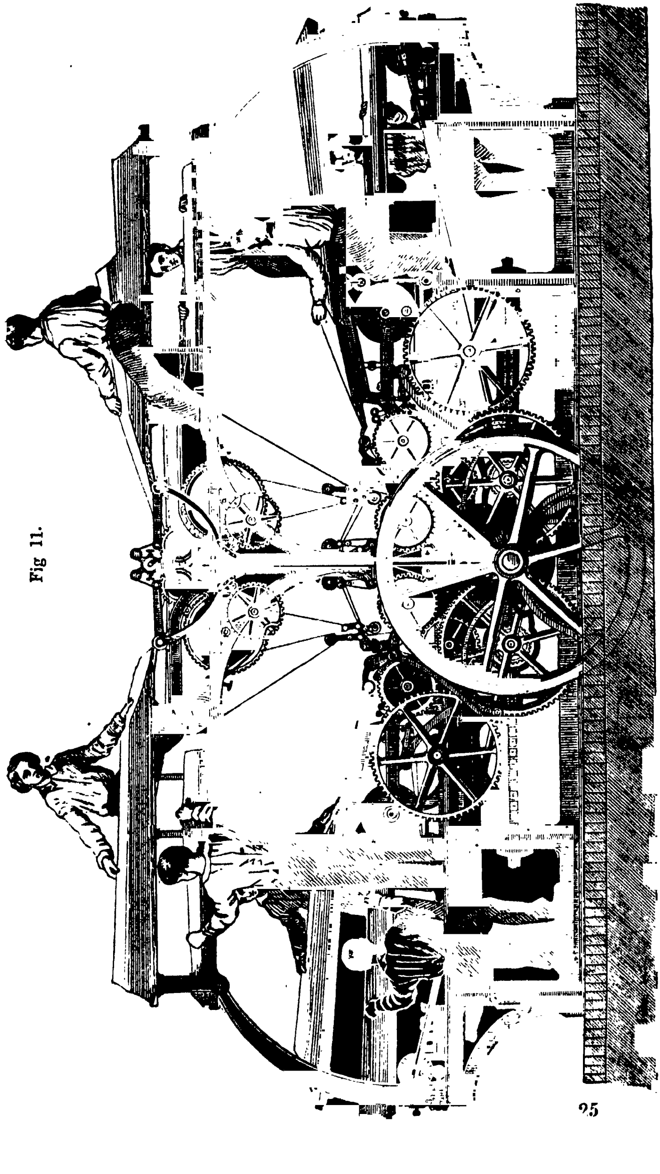


Fig 11.

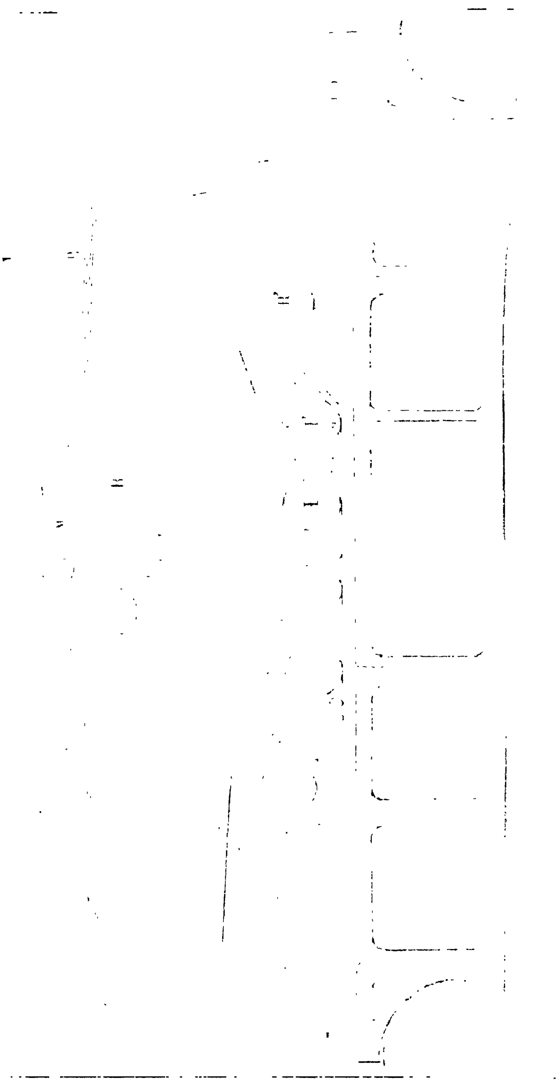


Fig. 12.

in the usual manner, at T, T′, T″, T‴, and T″″, to spread the ink on the types.

It will be perceived that the power of this press is equal to that of *The Times*, the difference being that *The Times* prints 12000 sheets on one side only, while this prints 6000 on both sides. *The Times* machine requires eight layers-on and eight takers-off, being double the number required by Marinoni's press. It must, however, be observed that, in the practical management of newspaper printing, as conducted in *The Times* office, the power of Marinoni's press, though in a certain sense equal to that of *The Times*, would be altogether insufficient; for it is indispensably necessary for that journal to print 60000 copies on one side of the paper during the last five hours of the morning. The matter allotted to the other side of the paper is so selected that it can be composed and printed in the earlier part of the night, or even of the previous day; the pressure falling exclusively on the matter which occupies the other side of the paper, consisting chiefly of the latest intelligence and Parliamentary reports.

It may be asked, therefore, how the journal of *La Presse*, of which the circulation, though inferior to that of *The Times*, is still very large, can be printed with the necessary celerity? The answer is, that *La Presse* does not contain as much as the tenth part of the letter-press of a copy of *The Times*, and that therefore, it is found practicable to compose the matter in type twice or oftener, so as to produce two or more distinct *forms*, as they are called, which are put to work at as many different presses. The expense of composition is further economised at the printing office of *La Presse* by stereotyping the matter, which is composed at a sufficiently early hour to admit of that process, the stereotype plates being melted down the next day. By this expedient double or triple composition is only necessary for the intelligence which comes too late to allow of being stereotyped.

27. **Marinoni's Book-printing Machine.**—A convenient form of printing-engine for books, constructed by the same engineers, is shown in fig. 13, by which, however, the sheets are printed on one side only. The layer-on delivers the sheets upon the board M (fig. 14), from which they pass round the printing roller I, and are discharged as indicated by the arrow upon the receiving-board R. The rollers for delivering and spreading the ink on the types are arranged in the usual way.

28. **Newspapers.**—Of all the applications of printing to the uses of life, that which has conduced most to the advancement and improvement of the art has been the printing of newspapers. These organs of public opinion and intelligence combine the conditions which require from the printing press the greatest con-

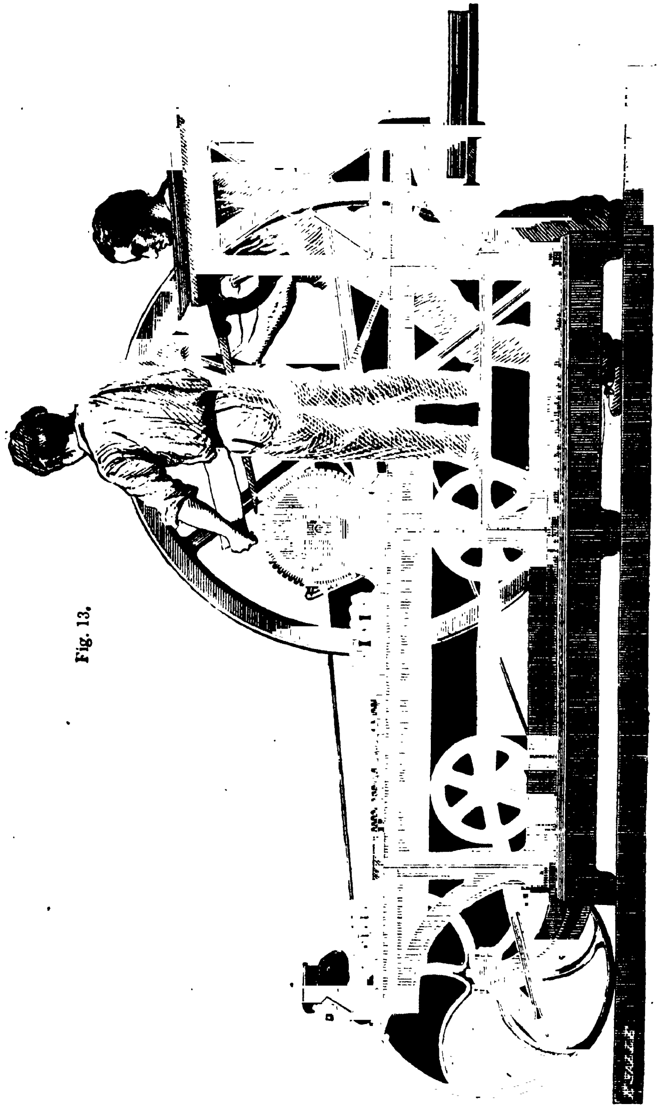
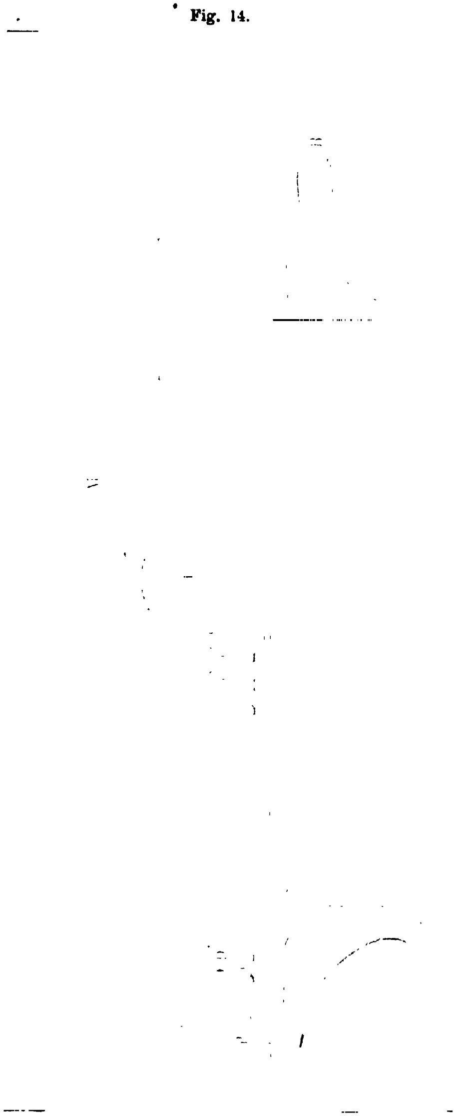


Fig. 13.

Fig. 14.



ceivable degree of perfection. Extreme rapidity of composition combined with the greatest attainable celerity of press-work are above all things indispensable, and how far these objects have been attained by the modern printing-machine, will be understood by what has been stated in the preceding paragraphs. On the other hand the improvement in the machinery of printing, which the exigencies of journalism have thus produced, have themselves reacted on journalism in the most surprising manner, so that the feats of art now accomplished in the establishment of the London daily papers, justly excite the admiration and the wonder of all well-informed persons. These newspapers are remarkable for the vast mass

and variety of intelligence which they contain, the celerity with which they are printed and circulated, and the accuracy and copiousness of the reports which they afford of the proceedings of all public bodies. These results are obtained by an enormous expenditure of money and a minute and judicious division of labour. A corps of able and intelligent reporters is maintained, whose duty it is to attend the Houses of Parliament, the Courts of Law, Police Offices, and all public meetings. These relieve each other at short intervals of from half to three-quarters of an hour, when they return successively to the office of the journal and there write out in long-hand the substance of their short-hand notes. These are immediately delivered over to the compositor, who proceeds to set them up in type, and when a column has thus been composed it is handed over to the reader, after receiving whose correction it is returned to the compositor, who introduces the corrections into the columns of type. A proof being taken it is laid before the editor who decides the part of the paper it is to occupy, and whether it may need alteration or abridgment. It happens thus in the case of long debates, and sometimes in the case of long speeches, that a part will be actually set up in type and printed in proof before the remainder has been yet spoken.

29. **Reporters.**—In appreciating the functions of reporters, it is a great though very common mistake, to suppose that their duty consists merely in reproducing verbally the speeches delivered. If this were to be done no journal, however great its magnitude, would be sufficient to contain even a small fraction of the matter reported. The reports are therefore necessarily abridgments, with the exception of certain passages of striking importance, occurring occasionally in the speeches of the most eminent public men, and these can always be distinguished in the reports by the use of the first person instead of the third. The reporter takes therefore not verbatim notes but merely abridged memoranda of what is said, and as he remains in attendance only for the brief interval of half an hour or a little more, his memory by practice enables him to supply the lacunæ, so that when he arrives at the office of the journal he is enabled to write out a good abridged report of what he has heard. It is in this admirable capacity for judicious abridgment that the skill of the reporter, and more especially of the parliamentary reporter, is shown.

It will easily be understood from what has been here stated, that a well-conducted journal in London is obliged to maintain a large corps of reporters. They are generally classified according to their particular abilities and fitness. The highest class being parliamentary reporters, who are understood to be paid at the rate of about 5*l.* per week during the session of parliament. The law

reporters are a peculiar class requiring special qualifications, and are generally barristers who have not yet obtained sufficient practice to occupy their time. Police reporters form another distinct and peculiar class, who supply that part of the journals to which are consigned the proceedings of the police offices.

In fine, there is another class of agents for the supply of general intelligence, whose business it is to collect information on all subjects in all parts of the town.

30. **The Court Newsman** is not to be overlooked. This personage supplies daily to all the journals, those paragraphs in which are found recorded the movements of the Sovereign and the Royal Family; who was invited to dinner at Windsor or Buckingham Palace; what music was performed at and after dinner, and by what band, and so forth. The same functionary is entrusted to supply accounts of the various parties and entertainments given by the aristocracy.

31. **Foreign Correspondents.**—Among the staff of daily London journals the foreign correspondent holds a conspicuous place. The principal journals maintain such a correspondent in all the principal foreign capitals, and, in case of war, such a correspondent accompanies the army and the fleet. The foreign correspondents maintained in the principal European capitals usually keep bureaux, and have assistants, who collect news and supply reports. A despatch is forwarded to London always once, and often twice, a day, the telegraph being resorted to when news of considerable importance is required to be transmitted with more promptitude.

32. The rapidity with which the circulation in newspapers has increased in the United Kingdom during the last century, but more especially during the latter half of it, may be judged from the following facts.

In the annexed table is given the total number of newspapers circulated in this country during the years expressed in the first column:—

Years.	Number circulated.	Average annual increase.
1751	7,412575	
1801	16,085085	173450
1821	24,862186	438855
1831	35,198160	1,033597
1841	59,936897	2,473873
1849	78,792934	2,357005

Thus it appears, that while the average annual increase of the circulation of journals, in the latter half of the last century,

was limited to 173000, the average increase during the first twenty years of the present century was 439000; the next ten years this rate of increase was more than doubled, and in the succeeding period it was augmented in a sixfold ratio. The total circulation in 1849 was more than ten times the circulation in 1751.

By comparing the circulation of journals with the population, an estimate may be obtained, if not of the diffusion of knowledge in general, at least of that description of information of which journalism is the vehicle. In the following table are given the amount of the population at the epochs above mentioned, and the number of journals circulated per head of the population.

Years.	Population.	Number of journals per head.
1751	6,377574	1·1
1801	10,942646	1·5
1821	14,391631	1·7
1831	16,539318	2·1
1841	18,720394	3·2

Thus, relatively to the population, the circulation of journals had increased in a twofold proportion in 1841, as compared with 1821, and in a threefold ratio as compared with 1751. Taking the population of Great Britain in round numbers in 1849, the ratio of journals to the populations would be 4 to 1, being an increase in the same ratio on the circulation in 1751.

So far, therefore, as the circulation of journals can be regarded as an exponent of the diffusion of knowledge, a greater amount of general information prevails now than prevailed a century ago in a fourfold proportion.

Since the dates of these returns, a vast change has been made in the circulation of journals, by the abolition of the newspaper stamp and reduction of the advertisement duty. Before the abolition of the stamp, the amount of the daily circulation of each journal was known by the Stamp-office returns. The average daily circulation of *The Times* was then about 40000, or about double the aggregate circulation of all the other morning journals. Since the abolition of the stamp duty, and the consequent reduction of the price of the journals, a considerable increase of circulation has taken place as well in *The Times* as in the other journals, and we shall not perhaps overrate the present circulation of the London morning newspapers if we put them down in the aggregate at 100000.

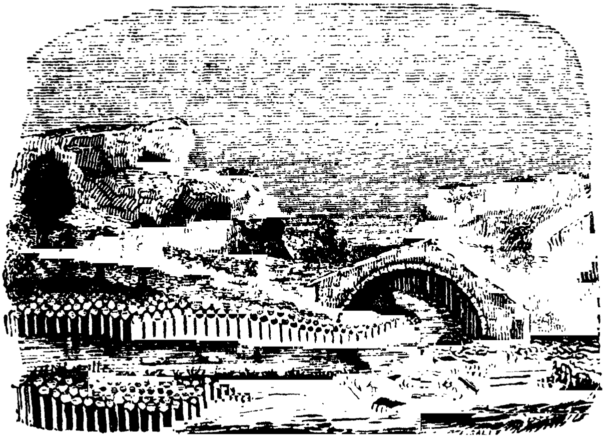


Fig. 31.—BASALTIC CAUSEWAY OF THE RIVER VOLANT. (DEP. ARDECHE, FRANCE.)

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER I.

1. The earth, a subject of long-continued observation and investigation.—2. Mathematical geography.—3. Physical geography.—4. Phenomena of the oceans and seas included in it.—5. Hydrology, meteorology, and climatology.—6. Political geography. —7. General subject of geography.—8. Geology.—9. Original fluidity of the earth inferred from its spheroidal form.—10. This form ascertained by observation and measurement.—11. The solid crust was formed while the earth was in a state of rotation.—12. Increase of temperature from surface downwards.—13. Within the crust the earth still in a state of fusion.—14. Subject of geology.—15. How the structure of the crust to a great depth is rendered manifest.—16. Section of the crust where no disturbance has taken place—strata occur in a fixed order.—17. Rocks in their geological sense.—18. Their classification in five principal divisions.—19. Lowest bed, being the foundation of the crust, consists of igneous rocks produced by the superficial cooling of the molten materials of the globe.—20. Materials of which the igneous rocks are formed.—21. Constituents of granite, feldspar, mica, quartz.—22. These components of igneous rocks agglomerated mechanically.—23. But the components themselves are chemical compounds. — 24. Varieties of granite—porphyry.—25. Gneiss.—26. Secondary rocks.—27. Transition or metamorphic rocks.—28. Stratification.—29. Produced by aqueous

deposition.—30. Stratified rocks of aqueous origin.—31. Circumstances corroborating this inference.—32. Stratified and unstratified rocks.—33. Condition and materials of transition rocks.—34. Animal remains found in them.—35. No vegetable remains—probable reason. —36. Fish and annelidans.—37. Stratified rocks in general.—38. Secondary rocks.—39. Vast quantity of organic remains deposited in them.—40. Tertiary rocks. — 41. Diluvium, alluvium, and surface soil.—42. Subdivision of these principal groups of strata. — 43. General inference as to the condition and ages of stratified rocks.—44. They constitute a chronological scale. — 45. Complexity and defects of geological nomenclature.

1. IT cannot be matter of surprise that of all the great bodies of the universe the earth, which has been assigned by the Creator as the habitation of the human race, has received the largest share of attention on the part of those who have devoted their faculties to the observation and investigation of nature. Regarded in different points of view it has formed the exclusive subject of several branches of science.

2. Taken in its entire mass, and considered in relation to the other bodies of the solar system, it constitutes the subject of MATHEMATICAL GEOGRAPHY, which includes the solution of such problems as the determination of the magnitude of the earth—its exact form—its relation to the other bodies of the solar system—its annual motion round the sun which produces the apparent movement of that luminary through the signs of the Zodiac—its diurnal rotation which produces those apparent motions of the firmament which cause the vicissitudes of day and night—the peculiar position of its axis which produces the succession of seasons—the division of the globe into zones and climates, and the system of imaginary circles of latitude and longitude which supply the means of expressing the position of all places on the globe, relatively to each other, and to the equator and poles.

3. The earth, viewed in regard to the various physical states of its surface, constitutes the subject of PHYSICAL GEOGRAPHY, which includes a description of the distribution of land and water—the extent and configuration of continents and islands—the elevation and prevailing direction of mountain chains—the form, extent, and direction of plains and valleys—the general altitude of the surface of the land above the common level of the sea—the effects of soil and climate, and the local distribution of animal and vegetable productions.

4. This division of geographical science also includes the various phenomena of the ocean and seas, their depth, saltness, and temperature, the prevailing direction and velocity of ocean currents, the extent of the polar ice and circumstances incidental to it.

5. The subdivisions of physical geography are sometimes denominated HYDROLOGY, which includes all that relates to the ocean and seas; METEOROLOGY, which includes the investigation of atmospheric phenomena; and CLIMATOLOGY, which involves the consideration of the mean temperature of different countries, the altitude of the line above which there is perpetual snow, the prevailing winds, the barometric pressure, the annual quantity of rain, and so on.

6. The earth, considered as the abode of mankind, distributed into different nations and placed under different forms of government, constitutes the subject of POLITICAL GEOGRAPHY, which therefore includes the consideration of the moral and social condition of different peoples, their language, religion, forms of government, and civilisation, and the population, resources and local relations of different countries.

7. It appears, therefore, that these several divisions of geographical science are limited to the appearances and phenomena developed upon the surface of the earth, in the waters which partially cover it, and in the atmosphere by which it is surrounded.

8. Another, and not less important department of science concerning the earth, relates to the condition and structure of those parts of the globe which lie between its surface and its centre, and which constitute the subject of GEOLOGY.

9. In mathematical geography and astronomy, certain physical circumstances attending the interior of the earth have been developed. Thus it is proved that the density of the globe gradually increases from the surface to the centre; and from its peculiar form it is inferred that, at the epoch of its formation, the materials composing it must have been in a fluid state. It has been already shown in our Tract on the "Earth," that the form of the globe is what in geometry is called an *oblate spheroid*, a figure somewhat resembling an orange or a turnip. By reason of this figure, the earth is flattened at the poles and bulged out at the equator. Now it is proved in mathematical physics that if a fluid globe have a motion of rotation on one of its diameters as an axis, the centrifugal force of the matter composing it will cause it to bulge out at the equator and to flatten at the poles, so that all sections of it made by planes passing through the axis are ellipses, and the degree of the elliptic form of these sections will be so much the greater as the velocity of rotation is more rapid; and so closely connected is this degree of ellipticity with the velocity of rotation, that mathematicians are able to assign the exact form of the elliptic section which must correspond to each particular velocity of rotation.

10. Before the exact form of the earth had been determined by

direct observation and measurement, mathematicians had already ascertained by computation what ought to be its form consequent upon its rotation upon its polar axis, and the time in which it is actually known to rotate, and the result of their computations was afterwards found to agree with the utmost possible numerical precision with the actual form which the earth was proved to have by immediate observation and measurement.

11. It is therefore inferred from this that the earth, in its original state, and before it assumed its present condition, was a fluid mass, and that while in this fluid state, it received the diurnal rotation by which it is now affected, and which produces the vicissitudes of day and night. It was, therefore, after having assumed this spheroidal form, that its superficial parts hardened and solidified, and after undergoing a certain succession of changes assumed their present condition.

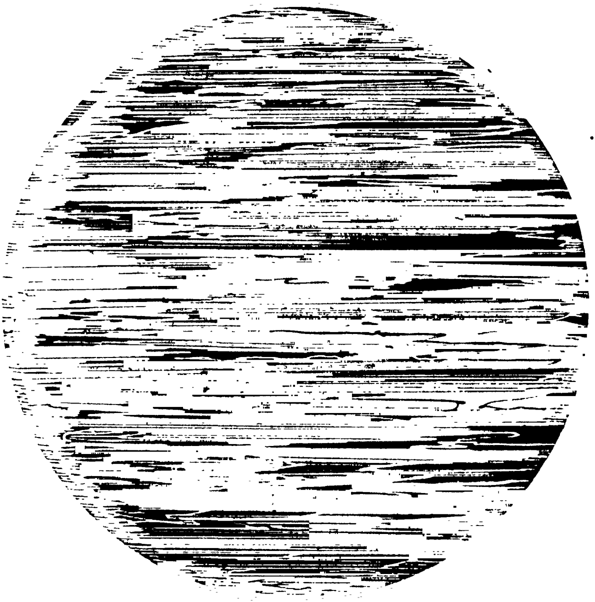
12. It has been also shown in our Tracts on "Terrestrial Heat," and on "Earthquakes and Volcanoes," that when we penetrate into the crust of the earth by mines, boring, or other artificial means, the temperature is found to undergo a gradual and regular augmentation, and this augmentation being continuous, so far as direct observation has been carried, may be assumed by analogy to increase to a still greater depth in the same proportion—a conclusion which also is verified by the phenomenon of hot springs rising from a considerable depth, and by various volcanic effects. Assuming this gradual increase of temperature to go on indefinitely in descending towards the centre, it has been shown that at a certain depth the temperature must be such that even the most refractory constituents of the globe would be reduced by it to a state of fusion.

13. The increase of temperature being at the rate of about a hundred thermometric degrees per mile, it would follow that at the depth of about 40 miles, or about the 100th part of the entire distance from the surface to the centre, we should arrive at a temperature of 4000°, at which it is quite certain that no part of the matter composing the earth could remain solid. It is therefore inferred, without the necessity for extreme numerical precision, that the earth is a spherical shell, the superficial part only being solid—all the central part being in a state of igneous fusion—the thickness of the solid crust being, as just stated, about the 200th part of the entire diameter. A section of it would be such as is represented in fig. 1.

If, therefore, as we have already stated in our Tract on "Earthquakes and Volcanoes," the egg of a fowl be imagined to represent the earth, its shell would be much too thick to represent its solid crust.

It is no rhetorical exaggeration that the globe we live on is a stupendous, but very thin spherical shell, charged with liquid fire; and if such be the case it may naturally be asked how it happens, that so thin a crust supported on a fluid so mobile can maintain that

Fig. 1.



general state of stability which characterises it so strongly, that it is referred to in times ancient and modern as the type of all that is most solid and most durable. An answer to this reasonable question will be collected from all we shall have to explain in the present Tract.*

14. The investigation of the structure and condition of this solid crust of the terrestrial spheroid, extending from the fluid

* According to Mr. Hopkins, the thickness of the crust is subject to much local variation, being very unequal on its inner surface. He considers that it is probably cavernous, and that masses of fluid mineral matter may be distributed through its cavities. According to him the thickness in some parts may be as great as 800 or 1000 miles. See Memoirs on the State of the Interior of the Earth, in the Philosophical Transactions from 1839 to 1842.

nucleus upon which it is supported to the surface, constitutes the subject of geology.

15. Considering that however thin may be the crust of the earth as compared with its diameter, its absolute thickness being at least from 30 to 40 miles, and that this very far exceeds any depth which is accessible to direct observation, it might be imagined that all attempts at an analysis of its structure would be vain and futile. A circumstance nevertheless which at first view would seem to throw difficulties insurmountable in the way of the solution of this problem has, on the contrary, happily facilitated it. This circumstance consists in certain local irregularities in the actual state of the solid crust. What man could not do, the accidental effects of internal forces has done for him. The solid crust has been locally disrupted, so that its section in some cases for many miles of depth has been turned upwards and exposed to direct observation. It will be sufficient here to allude briefly to this as one of the principal means, by which the structure of the terrestrial crust has been ascertained. The point will be more fully developed hereafter.

16. To explain the condition and structure of the terrestrial crust, we will suppose in the first instance a part of the earth's surface to be selected, which throughout a considerable extent is plane and level, and which has been subject to no derangement of structure by internal convulsion, so that the materials which form it, extending from the surface to the internal igneous fluid on which it rests, have remained in their normal and original order and state. If we imagine a vertical section of the crust in such a situation to be made extending indefinitely downwards, it will be found to consist of a series of strata superposed in a certain fixed order, each stratum, taken in succession, consisting generally of the same constituents in the same state.

17. The matter composing these strata is called by geologists ROCKS, a term used in this science in a sense somewhat different from its common popular signification. ROCKS in the geological sense does not necessarily imply masses of stone. It signifies any agglomeration whatever of matter which may be found to enter into the composition of the crust of the earth. In this sense clay and sand come under the name of ROCKS as well as granite and marble.

18. Taking then the term rocks in this extended sense, the successive strata composing the shell of the earth is found to consist of different layers of rock, each layer being characterised by rocks existing in a peculiar state of aggregation.

The strata thus superposed, and extending from the fundamental layer which rests immediately upon the matter in igneous

fusion within the terrestrial shell upwards to the surface, are very numerous.

They have, however, been reduced to the five following classes proceeding upwards.

1° The igneous rocks.

2° The transition or metamorphic rocks.

3° The secondary rocks.

4° The tertiary rocks.

5° The diluvial and alluvial layers of matter upon which the superficial soil is spread.

We shall first briefly notice these five great layers, each of which, however, as will hereafter appear, consists of numerous subordinate courses or strata.

19. The lowest or fundamental layer, called igneous rocks, consists exclusively of agglomerations of mineral masses in a state of crystallisation. This is the condition which matter would necessarily assume, and which it could only acquire by having been gradually cooled and solidified, after being brought to a state of fusion by a great elevation of temperature. Under such circumstances its chemical constituents would group themselves according to their mutual affinities, and would assume the various crystallised forms proper to them. After cooling and solidifying, the materials would present the appearance of an agglomeration of crystals thrown arbitrarily together and without regularity or order. Now this being exactly the appearance presented by the rocks which form the foundation of the crust of the globe, it is inferred that they were originally in a state of igneous fusion, and that by the gradual loss of heat by radiation, they were superficially cooled and solidified. The parts of the primitive rocks which have been brought under the observation of geologists are considered as forming the external parts of this solid layer.

These rocks are from circumstances here explained often denominated PLUTONIC OR IGNEOUS ROCKS, or ROCKS OF IGNEOUS ORIGIN.

20. Those primitive layers, which may be regarded as the original materials of which the entire crust of the globe is formed, consist chiefly of that rock familiar to all observers of mountainous countries called GRANITE, the most imperishable of all stones, and therefore the most precious for the purposes of construction. This granite is mixed in the fundamental layer in smaller proportions with the minerals called AMPHIBOLE, PYROXENE, and PERIDOTE.

21. Granite is an agglomeration of the crystals of three minerals, called FELDSPAR, MICA, and QUARTZ. Feldspar is the soft grey part of the granite, which is easily scratched. The

oxides of iron and manganese are occasionally mixed with this constituent of granite, and though present in extremely minute quantity, produce nevertheless a very striking appearance, rendering the rock white, cream-coloured, or red, according to their varying proportions.

MICA is the shining glossy particles of the stone, which reflect light like bits of glass or metal. The name is derived from "MICANS," *glittering*. Mica may be seen in many other stones, as also in sand.

QUARTZ, which appears in granite in the form of white crystals, is the substance known as SILEX or SILICA, or the EARTH OF FLINTS, and is one of the hardest and most abundant of mineral substances, entering largely into the composition of many other mineral masses. It is from this constituent, chiefly, that granite receives its hardness.

Silica is familiarly known as ROCK CRYSTAL.

22. It must be remembered that the several materials of which the igneous rocks are thus composed, are not combined together chemically. They are not combined for example in the same manner as are sulphur and oxygen, when these constituents produce vitriol. They are on the contrary merely agglomerated and brought into mechanical juxtaposition, forming a solid mass by the mere cohesion of crystal to crystal, so that by the action of mechanical force it would be possible to resolve the rock into its component parts.

23. Each of these constituents is, however, itself a compound. Thus feldspar is a compound of the silicates of several chemical substances, such as alumina, lime, and potash, or soda—that is, it is a combination of these severally with silicic acid.

Mica is composed of like silicates, with the addition of silicate of iron.

Quartz is in fact silicic acid itself. It will appear, then, from this statement, how important a part silex, or earth of flints, plays in the formation of the globe.

24. If the constituents of the igneous rocks were combined, one with another, chemically, instead of being mechanically juxta-posed, they would, according to a general law of nature, always be found to prevail in the same rocks in one invariable numerical proportion; but being, as explained above, merely agglomerated by cohesion, without any chemical union, they may exist in any proportion whatever, and hence have arisen a corresponding variety of granites. In some specimens the quartz and mica are altogether absent, and then the granite, consisting of feldspar only, in the pasty and crystallised state, takes the name of PORPHYRY.

In other specimens, the proportion of feldspar being large, and that of mica and quartz small, the rock is called PORPHYROUS GRANITE.

25. In general, the little laminæ of mica are distributed irregularly through the granite, their faces being turned in all conceivable directions. In certain specimens, however, they are observed to be placed parallel to each other, so as to give the rock a lamellated, slaty, or schistous texture. The granite, in such cases, takes the name of GNEISS, from the Danish "*gnister*."

26. Having thus briefly described the composition and condition of the fundamental layer of matter, upon which the solid shell of the earth is based, and indicated the circumstances and characters which are evidence of its igneous origin, we shall now proceed to explain the condition and character of the superincumbent strata, which, as will presently appear, have had an origin of a very different kind, and dates of incomparably more recent formation.

27. The strata which rest immediately upon the igneous rocks have been denominated TRANSITION or METAMORPHIC, inasmuch as they partake partly of the character of the igneous rocks, and partly of that of the rocks incumbent upon them. They partake, in certain instances, of so much of the former and so little of the latter, that in the earlier epochs of geological research, they were classed with the igneous rocks, from which, nevertheless, they are distinguished by sufficiently evident marks of incipient stratification.

28. It has been explained that the materials composing the igneous rocks are confusedly and irregularly agglomerated without the least appearance of even an approach to any regularity of structure, and it has been shown, that this is at once the consequence and evidence of their igneous origin. Such, however, is not the character of the superincumbent rocks. The materials of which these are severally composed are found to be distributed, one over another, in regular layers, bounded by parallel and horizontal surfaces, resembling the courses of masonry. Now such a distribution never could have resulted if these, like the primary rocks, had, previously to their formation, been in a state of fusion.

29. Such an arrangement, on the other hand, is precisely that which would ensue, if the materials, composing the strata, having been mixed with, and suspended in water, had, after the fluid became tranquil, gradually subsided and settled at the bottom. In such a case, the matter thus subsiding would be deposited in a regular series of layers, one above the other, with level and parallel surfaces. The lowest layer would be composed of the heaviest part of the matter held in suspension by the water, that

being the most prompt to sink. Next would come layers of less ponderous matter, and then another lighter still, and thus layer upon layer would be deposited until the whole of the suspended matter would have subsided.

If from any cause after this subsidence the water retired, the ground forming its bottom would be left bare, and the dry land would, if it were excavated, be found to consist of the succession of strata here described.

Now if the actual layers composing the successive strata, which are superincumbent on the igneous rocks, did really in their origin proceed from such a cause, it might be expected that they would succeed each other in the order here indicated, those most apt to subside holding the lower position, and such accordingly is found to be the case.

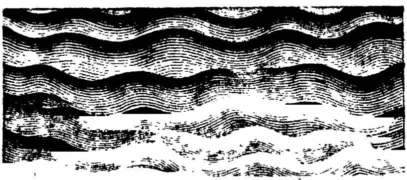
30. In accordance with these results of observation on the strata forming the crust of the earth, and with concurrent evidence deduced from other appearances, it has been inferred, with a degree of probability amounting to moral certainty, that the stratification has resulted from such a series of physical causes as those above described. Each stratum consisting of a series of parallel layers is assumed to have been a sedimentary deposit precipitated from water, by which the surface of the solid part of the globe has been at former epochs covered, and that these waters having become quiescent before retiring, the matter suspended in them was deposited in layers having more or less regularity, their surfaces being parallel and level, or nearly so.

31. Among the many collateral circumstances which corroborate these conclusions may be mentioned two.

First, the frequent occurrence in the bounding surface of the layers of the form of the ripple of water, as it is observed in the sands of the sea shore after the fall of the tide has laid them bare.

An example of such traces left upon the beds of carboniferous limestone and Portland-stone, in the neighbourhood of Boulogne, is shown in fig. 2.

Fig. 2.



Secondly, by the remains of various aquatic animals and plants, which are often preserved in their natural position, in

which they were tranquilly buried by the matter deposited upon them. Numerous remains of crustacea and mollusca are thus found in perfect preservation in strata situate at great distances from the shores of the sea, figs. 3, 4.

Fig. 3.

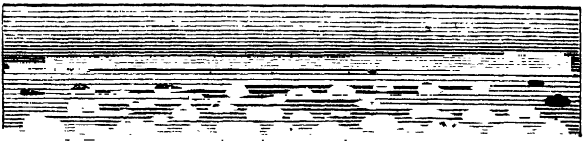
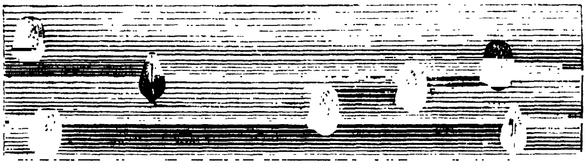


Fig. 4.



These phenomena will be more fully explained hereafter.

32. These circumstances establish a marked distinction between the igneous and the superincumbent rocks. The latter, consisting of matter distributed in regular and horizontal layers are called STRATIFIED ROCKS, while the former consisting of materials agglomerated without any semblance of order are called UNSTRATIFIED ROCKS.

As the unstratified rocks are called PLUTONIC or IGNEOUS ROCKS, the stratified are denominated NEPTUNIAN or SEDIMENTARY ROCKS, and sometimes ROCKS OF AQUEOUS ORIGIN.

33. The transition or metamorphic rocks, which rest upon the igneous rocks, show traces of stratification combined with such partial crystallisation as may be inferred to have arisen from their contact with the highly heated surface of the rocks below them. The principal rocks composing the transition-system, are the gneiss, already described, crystallised limestone, quartz, hornblend, thick layers of the rock called the old-red sandstone, and many varieties of slate and shale.

34. Independent of the existence of distinct stratification in these, they are still more decidedly distinguished from those of igneous origin by the deposits of animal remains found in them, which, though neither numerous nor of a high order of organisation, are nevertheless present in sufficient quantity to put aside in the most conclusive manner all other suppositions, than that of sedimentary formation and aqueous origin.

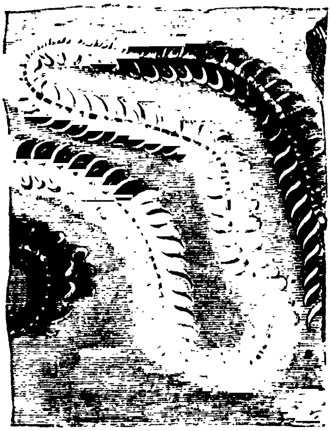
35. It has been assumed by many geologists, that although

animal remains have been found in these transition-rocks, no traces of vegetables were discovered there, from which it was inferred that the existence of animal life upon the globe preceded that of vegetation. M. d'Orbigny has shown, however, that such is not the case. The remains of various marine plants have been found by Mr. Hall in the lower Silurian strata in the State of New York. The coal-mines of Vallongo, in Portugal, are in the same strata; and the richest coal deposits of Spain are in the Devonian formation. It must, therefore, be considered that animal and vegetable life were always co-existent, as indeed is apparent, *à priori*, inasmuch as animals which do not feed on each other must necessarily feed on vegetables.

Organic remains of animals have been found in the superior layers of transition-rocks, which present singular interest as being the earliest examples of life traceable in the growth of the earth. It would seem, that after the external parts of the igneous matter had been hardened by the process of cooling, the first sedimentary layers deposited upon it became the habitation of certain races of organised beings.

36. Among these the researches and observations of Professor Phillips have brought to light various species of small fish, and there have been found, near Llampeter in North Wales, in the same strata, traces of a species which the late Mr. William Macleay, a profound

Fig. 5.



naturalist, pronounced to be a sea-worm of the class of Annelidans, being the first in Cuvier's classification of articulated animals.

The remains of one of these sea-worms, *Nereites Cambrensis*, found at Llampeter, is shown in fig. 5. The body of this creature consisted of about 120 joints.

37. In fine, then, we find that upon the igneous rocks as a foundation the superficial structure of the earth has been erected, consisting of a series of layers or courses of natural masonry, one placed above another—the formation of each of which has been the work of countless ages; that transition-rocks were the first and earliest of these, while those which form the surface of the earth, and are the habitation of the existing organised tribes, were the last; and that the epoch at which these latter tribes, including the human race, were called into existence, remote as it must appear, compared with all measures of time familiar to us, is recent when referred to that system of chronology which is written upon the crust of the globe.

38. Above the transition-rocks, which, as we have stated, were first placed in the class of primitive rocks, succeed a series of layers which have been denominated SECONDARY ROCKS. These consist chiefly of chalk, clay, argillaceous slate, shale, red and brown sandstone, limestone, iron and lead ore, and coal. They abound in organic remains, animal and vegetable, in a high state of preservation, the minutest parts being often perfectly observable.

39. The extent to which the earth was the theatre of organic life, at the epochs of the deposition of these numerous strata, may be conceived when it is stated that, in 1834, a German naturalist and geologist counted no less than 9000 species, the remains of which, at that date, had been found below the superior limits of the stratified rocks, not one of which has ever existed since the earth became the habitation of man.

Among the animal remains which abound in these secondary strata may be mentioned corals, crinoides, mussels, trilobites, fishes, reptiles, insects, marine and fresh-water shells, sponges, and animalcules countless in number.

Of the reptiles, the most remarkable are various species of lizard-shaped animals, constructed on a scale of colossal magnitude, called Saurians, from the Greek word Σαυρος (Sauros), lizard. These have been variously denominated megalosaurus, plesiosaurus, ichthyosaurus, and so on.

40. Upon the secondary rocks repose a series of strata of more recent deposition, called on that account TERTIARY ROCKS. These consist of a thick bed of clay, limestone, sand, pebbles, and white sandstone. They abound in organic remains, which are distinguished from those of the lower and more ancient strata by including a considerable proportion of the still living species. Thus the lowest strata of the tertiary rocks contained 5 per cent.,

and the superior strata 10 per cent. of the species found among the animal tribes which still continue upon the earth.

41. In fine, superposed upon these tertiary are several layers of earthy matter, upon which the actual organised world is placed. These are usually resolved into two beds, the lower of which, denominated DILUVIAL, consists of deposits of gravel and clay, with boulder-stones, rounded in different degrees by attrition, giving indication of having been carried from a distance by the *extraordinary* action of water, from which the general name DRIFT has been given to them.

The superior bed consists of sand, clay, and gravel, upon which the surface soil, which is the theatre of agriculture, rests. This consists of decayed and decomposed vegetable matter, mixed with more or less of the disintegrated matter of the inferior beds. This uppermost layer is produced chiefly by the *ordinary* action of water, and is denominated ALLUVIAL.

42. Such are the five principal groups of rocks, into which geologists have divided the matter which forms the shell of the globe. The transition, secondary, and tertiary groups, have each been subdivided into several layers or strata, each of which is distinguished by the peculiar sorts of mineral matter of which it is composed, and the peculiar species of organic remains which it contains. Geologists, however, are not agreed either as to the limits of the five principal groups, or as to their distribution into subordinate strata. Thus they are not agreed as to where each of the principal groups ends and the next begins. The rocks, which one calls *primitive*, another denominates *transition* or *metamorphic*. Those which one assigns to the upper part of the transition-system, another assigns to the lower part of the secondary system; and in like manner what one assigns as the highest strata of the secondary, another gives as the lowest strata of the tertiary. These discrepancies, however, arise more from the nature of the things than from any deficiency of our knowledge of them. Between one group and another there is no essential distinction, and their classification into primary, secondary, and tertiary, though convenient, is, like many other classifications, to a certain extent arbitrary.

43. From what has been stated, respecting the strata constituting the crust of the earth, the following consequences will follow:—

First. The unstratified and igneous rocks existed prior to the stratified or sedimentary rocks.

Secondly. The stratified or sedimentary rocks were produced in the chronological order in which they are found superposed, the most ancient being the transition-system, and the others being formed in the order of time in which they are superposed,

the oldest being the lowest strata of the secondary, and the most modern the upper strata of the tertiary; the intermediate strata have intermediate dates in the order of their superposition.

Thirdly. The sedimentary strata in their original and natural position were necessarily *level;* their bounding surfaces were horizontal and parallel. Wherever, then, they may be found in any other position, it must be assumed that they have undergone derangement of position by some disturbing cause *since their original deposition.* This derangement may arise either from the strata being heaved upwards by a pressure from below, or by their sinking downwards by their incumbent weight forcing them into some inferior vacuity.

Fourthly. Although the succession of strata constituting the series, from the primitive rocks upwards to the surface, is by no means invariable, and is subject on the contrary to many local variations, still its general character is such as has been described. If the sedimentary strata, proceeding from the lowest upwards, when complete, be expressed by the letters A, B, C, D, &c., it will sometimes happen, from local causes, that the actual series may be A, B, C, E, &c., or A, B, D, E, &c., or A, D, E, &c., but it can never happen that the series shall be D, B, A, C, &c. In a word, one or more strata of the series may be wanting, but their natural order is never inverted.

44. It appears, therefore, that the character and order of the sedimentary strata constitute a chronological scale indicative of the history of their formation. It is true that the value of the unit of this scale is not and cannot be known, inasmuch as the absolute intervals of time, necessary for the deposition of the strata severally, cannot be certainly determined. This, however, does not prevent the geologist from pronouncing with perfect certainty upon the *order* of time of their deposition respectively.

45. Although the series of strata above described have been deposited, subject to so many local disturbing causes, that there is probably no point on the entire surface of the globe, where a section would exhibit them complete, still by a careful and judicious comparison of observations, made in different localities, their normal arrangement and natural order of superposition has been ascertained, and geologists have grouped and classified them under a great variety of denominations. Owing to the absence of any general convention, no single system of nomenclature has been adopted, as has been so happily effected in chemistry, and though in a less degree, also in zoology. The consequence is that geology is overlaid with a complicated, confused, and discordant nomenclature, detrimental to the diffusion and even to the progress and extension of the science. Those

who desire to obtain even the most superficial acquaintance with it, are therefore compelled to familiarise themselves with a mass of most repulsive technicalities, in which the same thing is called by many different names, according to the varying views, tastes, and even personal caprices of the geological investigators who have devoted their labours to the researches in which it finds a place.

Names have been given to strata or groups of strata in some cases from the localities in which they are found at the surface, as for example the Jurassic, the Silurian, the Cambrian, and the Devonian groups. In other cases, names are derived from the prevalent materials constituting them, as the cretaceous, oolitic, and carboniferous groups. Other names have been adopted from the order of the deposits, as for example eocene, miocene, pleiocene, and pleistocene, from Greek words signifying the first dawn, or the earliest, less recent, more recent, and most recent.

Another set of names has been taken from the presence, absence, or dates of the forms of life exhibited by the organic remains found in the strata. Thus the strata, which are destitute of all such remains, are called AZOIC, from a Greek compound implying the absence of life. The term cainozoic is applied to the most recent strata, including organic remains, mesozoic to the middle strata, palæozoic to the ancient strata, protozoic to the first in which life appears, and hypozoic to those strata which lie below the range of all organic remains.

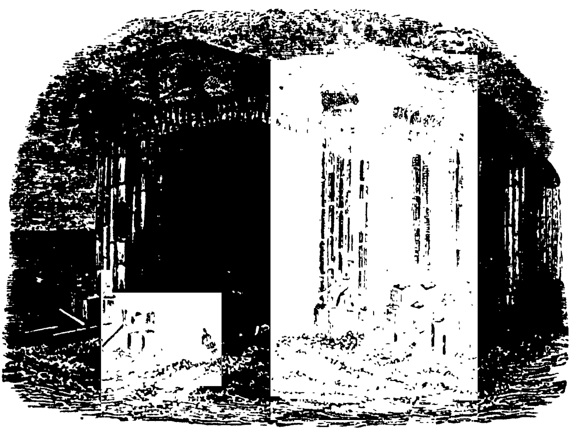


Fig. 37.—CAVE OF FINGAL, STAFFA.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER II.

46. General section of the terrestrial crust tabulated.—47. Approximate thickness of strata.—48. Probable time necessary for their deposition.—49. Recapitulation of the physical history of the globe.—50. Deposition of organic forms.—51. Alternate elevation and depression of the crust.—52. The strata are botanical and zoological museums of past creations.—53. The gradual increase of forms of life.—54. Creative power has always operated on the same general plan.—55. But has varied from period to period in details.—56. Animals created gradually; the more perfect being the more recent.—57. Tabular view of the progress of the animalisation of the earth.—58. Great increase of vertebrates in the tertiary period—No human fossil—Man characteristic of the present period.—59. Temporary existence of certain extinct genera and species.—60. Geological use of characteristic genera and species.—61. Examples—Trilobites characteristic of the Silurian strata.—62. Description of them.—63. Dr. Buckland's reflections on them.—64. Species characteristic of the lias—Ichthyosaurus.—65. Characteristics of the Wealden—Hylæosaurus—Iguanodon.—66. Characteristics of the chalk.—67. Ammonites, their distribution between the Silurian and chalk.—68. Fossil cephalopodes—Nautilus—Danians.—69. Fossil gasteropodes—Bigranulosa murchisonia—Cypræa elegans—Voluta elongata—Pterocera oceani.

46. A GENERAL idea of the series of stratified rocks, proceeding

downwards from the superficial soil, which is the theatre of agriculture, through the alluvial and diluvial deposits upon which it rests, and thence successively through the tertiary, secondary, and primary stratified rocks to the igneous ones which form the foundation of the terrestrial crust, may be formed from the following tabular statement (page 51), which we have compiled from the works of different geologists, and principally from that of Sir H. de la Beche, representing the order of the strata in Western Europe, and which in its general character will be found to correspond sufficiently with the condition of the terrestrial crust in most parts of the world, especially as regards its major divisions.

The strata, which in this table are denominated primary or palæozoic, are by some geologists included under the general denomination of secondary rocks. These must not be confounded with the igneous rocks, which are often called primitive rocks, and which are not stratified at all. The hypozoic or lowest beds of stratified rocks, together with the lower groups of the primary or palæozoic, are those which in the preceding paragraphs have been denominated transition or metamorphic rocks.

47. On contemplating the table, and on considering the peculiar super-structure which it exhibits, combined with the fact that each layer being a sedimentary deposit, must have been the result of an interval of time of considerable duration, two questions will naturally suggest themselves.

What are the dimensions of these several strata, and what the total thickness of the whole structure from the granite foundation on which it rests to the vegetable soil upon the surface, and what has been the probable interval of time required to produce each stratum.

Although certain and definite answers cannot be given to these questions, some degree of approximation may be made to them. The thickness of the several strata and groups of strata is subject to considerable local variation, nevertheless the indications of the limits of these variations in certain parts of the earth, which have been subject to geological survey of more or less accuracy may be useful.

Thus, the following are the estimated thicknesses of several strata, proceeding upwards from the transition-system to the surface in Great Britain.

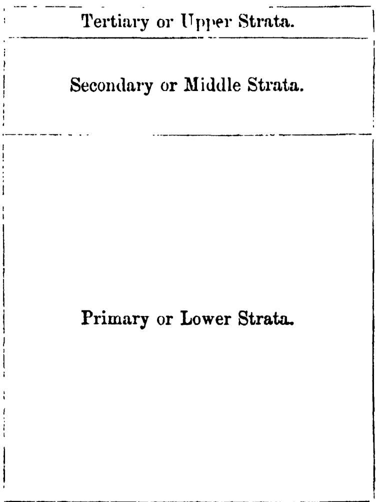
Gneiss system—a few miles.
Mica schist system—from a few yards to a few miles.
Cambrian system from one to five miles.

Llandeilo formation	1200 feet.
Caradoc formation	2500 ,,

Tertiary or Cainozoic.		Mineral accumulations of historic period, Pleistocene, Pleiocene, Miocene, Eocene.
Secondary or Mesozoic.	Cretaceous.	*Chalk of Maestricht and Denmark,* *Ordinary chalk with and without flints,* Upper green sand, Gault, Shanklin sands, Vecten Neocomian or lower green sand, Wealden clay, Hastings sands, Purbeck series.
	Jurassic or Oolitic.	Portland oolite or limestone, Portland sands, Kimmeridge clay, Coral rag with its grits, Oxford clay with Kelloway's rock, Cornbrash, Forest marble and Bath oolite, Fullers' earth, clay, and limestone, Inferior oolite and its sands, Lias upper and lower with its intermediate marlstone.
	Triassic.	Variegated marbles, Muschelkalk, Red sand stone, grès bigarré, bunter sandstein.
Primary or Palæozoic.	Permian.	Zechstein, dolomitic and magnesian limestone, Lower new red, conglomerate and sandstones, Coal measures.
	Carboniferous Limestone.	Carboniferous and mountain limestone with its coal, sandstone, and shale in some districts, Carboniferous slates and yellow sandstones.
	Devonian.	Modifications of old red sandstone.
	Silurian.	Upper Ludlow rocks, Wenlock shale and limestone, Woolhope limestone, Middle Caradoc sandstone and conglomerate, Lower Landeilo, Bala and Snowdon beds.
	Cambrian.	Barmouth sandstone, Penrhyn slates, Longmynd rocks, and various rocks below the Silurian.
Hypozoic.	Mica Schist.	Beds of mica schist consisting of quartz and mica with or without feldspar or garnets, chloritic schist, talc schist, quartz rock, clay slate, limited beds of iron ore.
	Gneiss.	Beds of gneiss consisting of laminæ of quartz, feldspar and mica; beds of mica schist, quartz rock, limestone, hornblende schist.
Primitive or Igneous.	Syenite, Porphyry, Basalt, Porphyritic granite.	The relative position and age of these rocks is more or less uncertain, though it seems probable that they may stand in the order here assigned to them.
	Granite.	This system of igneous rocks descends to an undefined depth, and is assumed to rest upon the internal liquid nucleus of the globe.

Wenlock formation	1800	feet
Ludlow formation	2000	,,
Old red sandstone	1000	,,
Carboniferous or mountain limestone	1500 to 2500	,,
Millstone grit	500 to 700	,,
Coal formation	3000	,,
Lower new red Pontefract rock . .	100	,,
Magnesian limestone	300	,,
New red sandstone	1000	,,
Lias	1000	,,
Lower or Bath oolite	400 to 900	,,
Middle or coralline oolite . . .	300 to 800	,,
Upper or Portland oolite . . .	200 to 800	,,
Greensand formation	——	
Chalk formation	——	
Lower tertiary or eocene, about . . .	1200	,,
Miocene formation.		
Pleiocene.		
Pleistocene.		

Rough as this approximation is, it may give some idea of the general thickness, at least, of the stratified part of the crust of the earth. It would appear from combining these results, that the total thickness of the stratified crust, as far as these observations go, varies from 10 to 20 miles. Of this thickness the lower, or palæozoic strata, constitute the principal part, as will be seen by the annexed diagram given by Professor Phillips.



48. To the question as to the lapse of time during which these successive sedimentary strata have been formed, it is impossible to give any answer even as definite as the estimates of their thickness. All that can be said is, that the deposition from turbid waters being generally a slow process, it may be imagined that intervals of time of vast duration must have been required for the formation of strata which measure many miles in thickness.

But besides the mechanical deposition of matters suspended in water, we find numerous traces of chemical decomposition, which could only have been effected in long intervals of time. Thus deposits of limestone lie in frequent alternation with sandstones and clays. These indicate a series of changes in the mode of action, by which the total stratified mass was produced, consisting of successive cessations and renewals in chemical and mechanical action.

In short all these effects combined with others, presently to be mentioned, lead to the conclusion that the period during which the human race and its contemporary tribes have existed upon the earth, is but a brief interval compared with the immense lapse of time occupied by the formation of the igneous rocks, by the cooling down of the superficial part of the fused matter, and the subsequent deposition of the stratified crust.

49. It may be useful here briefly to recapitulate the history of the globe, as we find it inscribed upon its crust.

Originally a mass of fluid matter, in a state of igneous fusion, it assumed the globular form in virtue of the mutual gravitation of its parts. Launched by the Creator into space with a motion of rotation round a certain diameter as an axis, it took the form of an oblate-elliptical spheroid, flattened at the poles, in virtue of the centrifugal force attending its rotation. The degree of spheroidal ellipticity being of course precisely that which corresponded to its velocity of rotation.

In this state its extremely exalted temperature would not only maintain the matter at its surface in a state of fusion, but would also keep a certain portion of the solid matter in a state of sublimation, and all the liquid matter in a state of vapour suspended in and mixed with the surrounding atmosphere.

After a continuance of greater or less duration in this state, the heat of the globe being continually radiated into the surrounding space, the temperature of its surface would be gradually diminished, and would, at length, fall below the point of fusion of the matter composing its surface, and consequently the superficial part would be solidified, and the globe would be coated, as it were, by a thin skin or shell of solid matter, enclosing within

it the matter still remaining in fusion. By the continued effect of radiation the temperature of the surface would continually decrease, and consequently the thickness of the solidified shell would be continually augmented. At length the superficial temperature would fall to such a point that the sublimated matter would be precipitated on the surface, and when the superficial temperature, falling still lower, would descend below the boiling point of water, a general condensation of the vapour sustained in the atmosphere would ensue, and the entire surface of the globe would be covered with an ocean of uniform depth.

If no disturbing force acted, this would have continued to be the condition of the globe; but the fused matter enclosed by the solid crust being subject to effects more or less irregular, and exercising unequal pressures, it was in some places protruded upwards, and in others depressed. In this manner certain parts of the solid crust were pushed above the level of the water, while others may have suffered corresponding depressions. Instead, therefore, of a universal ocean, the surface became diversified by land and water.

The action of the water upon the subjacent solid crust of the earth by erosion and disintegration and exposure to atmospheric action, produced various changes in its condition; and the parts thus washed off being subsequently deposited at the bottom of the waters, produced the incipient stratification which has been above described.

When the temperature of the globe was reduced to such a point as to be compatible with the existence of organised bodies, the first forms of life were called by the Creator into existence, and were such as were adapted to the then physical condition of the globe, being, as might be expected, exclusively marine tribes. When subsequently land emerged from the ocean, and by the condensation and precipitation of vapour rivers and lakes were formed, terrestrial, fluviatile, and lacustrine tribes were called into existence.

50. As each successive stratum was thus formed, the remains of the animals and vegetables of the epoch were deposited in them, and have accordingly been preserved to our times. Fluviatile and land animals, in greater or less numbers, were swept into the embouchures of rivers, and there deposited like the others. Lacustrine tribes were, in like manner, deposited in the bottoms of vast lakes or inland seas.

51. But, besides these, there are indications of other changes either gradual or sudden, which would explain the deposition of terrestrial organic remains in the strata. There are evidences that the swellings upwards and subsidence downwards of the

crust, by the internal movements of the fluid nucleus of the globe, caused various changes in the distribution of land and water, so that parts of the globe which at one time were raised above the waters, and inhabited by terrestrial tribes, were subsequently submerged; while other parts, being elevated, emerged from the waters and formed new continents or islands. Indeed, changes which are in actual progress, and which will be presently noticed more fully, show that such phenomena are still produced, though probably on a much smaller scale, than at the earlier stages of the growth of the earth when its crust, having less thickness and strength, offered less resistance to the internal movements of its fluid nucleus.

52. Since the strata were deposited during a succession of periods of long duration, each receiving the remains of the organised tribes which inhabited the earth at the period of its deposition, it follows that the organic contents of these successive strata may be regarded as so many museums presenting to us specimens of the zoology and botany of the globe at the successive periods of their deposition. By examining, therefore, these remains, we shall be able to compare with each other, and with the existing tribes, the living inhabitants of the globe at the several periods of the formation of these strata.

53. The first and most obvious inference suggested by such an analysis is, that the number and variety of organised beings has rapidly increased, from the period at which the earth became habitable to the present epoch. This is rendered evident by a comparison of the number of species found in a given thickness of strata, proceeding downwards from the surface, which has been estimated by Professor Phillips as follows:—

	Number of Species in 1000 feet thickness.
Tertiary	1410
Cretaceous	707
Oolitic	456
Triassic, Permian	82
Carboniferous	47
Silurian	27

These numbers represent the relative proportion of marine species, by far the most numerous of the organic remains, more especially in the lower strata. This calculation was based upon the results of observations made about 1834, and consequently the numbers given are considerably below what would be obtained from more recent observation; but their proportion, which is all that concerns us here, would probably not be altered by subsequent results.

54. Since, therefore, it appears that the globe, through a long series of periods, has been tenanted successively by various races and tribes, both animal and vegetable, it is a question of profound interest to determine whether creative power, in the production of these organic beings, has operated upon the same principles which are manifested in the structure of its actual inhabitants. It might, for example, be imagined that the forms of life at those distant epochs, existing probably under extremely different physical conditions, might be totally different from, and utterly incomparable with, those which now prevail. Or though they might agree in certain general principles and conditions, they might be expected to exhibit extreme differences in many important details. A survey, nevertheless, of the existing tribes, and a comparison of them with the remains found in the terrestrial strata, lead to the conclusion, that though the former inhabitants of the globe differed from the present in many minute details of their structure, yet they agreed in all the more essential principles.

Naturalists have resolved the existing animal kingdom into four primary divisions: the *Vertebrates*, the *Articulated* or *Annulated*, the *Mollusca*, and the *Zoophytes*.

Quadrupeds, birds, and fishes, for example, are Vertebrated animals; insects, spiders, and certain shell-fish, such as crabs and lobsters, present examples of Articulated animals; snails and oysters are examples of Mollusca; and star-fish, sea-blubber, and corals, of the class of Zoophytes.

Now a due examination of the organic remains deposited in the terrestrial strata leads to the conclusion, that they admit of precisely the same general zoological division.

But the analogy between present and past creations is still closer when those primary divisions are resolved into several classes. Thus the living vertebrates are divided into mammifers, birds, reptiles, amphibia, and fishes. In like manner the fossil vertebrates admit of precisely the same classification. We find among them all these classes and no others.

Again, the living articulated animals are resolved into the subordinate divisions of insects, myriapodes, arachnida, crustacea, and worms of various forms. A like subdivision is applicable to fossil Articulata.

Fossil, like living, Mollusca are resolved into Cephalopodes, Gasteropodes (snails), Acephala (oysters and mussels), Bryozoaria (plumatella), and others. In fine, the Zoophytes, fossil as well as living, are resolved into Echinodermata (sea-urchin, star-fish), Polyparia (coral), Infusoria (monads), and Spongyaria (sponges), all of which are found reproduced in the fossil state.

55. But when we descend to more minute distinctions we cease

to find the same close correspondence. Genera or families of the above-mentioned classes are found among existing species which are altogether absent from the fossils; and, on the other hand, numerous genera of fossil animals have no place in the existing animal kingdom. Of about 1000 fossil genera, somewhere about 500 are identical with those of existing animals, the other 500 being extinct.

The difference between the present and past creations is, as may be expected, still more remarkable when we come to compare species with species. Thus of 10000 well-ascertained fossil species there are not more than 200 or 300 which still survive.

56. Though the counterparts of all the principal divisions of the animal kingdom are thus found in the fossil state, they are by no means equally distributed through the strata. Nature, on the contrary, seems to have called them successively into existence, according to their increasing perfection of organisation,—the Mammalia, the most perfect of all, being the most recent in date; and the Zoophytes and Mollusca, the lowest in their organisation, the earliest.

Thus the first forms of life which appeared during the Silurian period were chiefly confined to the Zoophytes and other classes of the lowest organisation, the only Vertebrates then existing being fishes, and those in very limited numbers. The same forms, for the most part, prevailed upon the globe during the Devonian and Carboniferous periods. During the Permian and Triassic periods animated nature received no other increase than that of a few reptiles. No other classes were added to the creation during the long interval of the Oolitic period; but the number of species of reptiles, as of all the other classes just mentioned, were considerably increased.

The first appearance of birds was manifested during the Cretaceous period, but they were very limited in number until the Tertiary period.

It was not till the Tertiary period which immediately preceded the present epoch that Mammalia were created. Birds, reptiles, and fishes augmented in number and variety also during this period, as did various others of the inferior classes, such as Gasteropodes and Acephala.

It must be observed, however, that foot-prints of some Mammalia have been discovered in the Oolitic strata, and marks, supposed to be those of birds, in the Triassic.

57. In the following table, compiled from the very extensive tables of Paleontology, which accompany the work of Professor d'Orbigny, we have exhibited the commencement, continuation, and prevalence of the different classes of animals which inhabited

the earth during the successive periods from the Silurian to the Human. The relative numbers of each class prevailing at the different periods are indicated by the four following signs:

∵ least.
× more numerous.
△ still more numerous.
⊙ most numerous.

Classes.	Silurian.	Devonian.	Carboniferous.	Permian.	Triassic.	Oolitic.			Cretaceous.			Tertiary.			Human Period.
						Early.	Middle.	Late.	Early.	Middle.	Late.	Early.	Middle.	Late.	
Polyparia	∵	∵	∵	∵	∵	∵	×	×	∵	×	∵	∵	×	∵	⊙
Crinoidea	△	△	⊙		∵	∵	×	∵	∵	∵	∵	∵	∵	∵	∵
Ophiuroidea, Asteroidea, Echinoidea, Echinodermata	∵	∵	∵	∵	∵	∵	×	∵	∵	×	△	×	×	×	⊙
Bryozoaria	∵	×	×	∵	∵	∵	△	∵	×	△	⊙	×	△	×	△
Brachiopoda	△	⊙	△	×	×	∵	×	∵	△	△	△	∵	∵	×	∵
Acephala	∵	∵	∵	∵	∵	×	×	×	×	△	△	△	△	△	⊙
Marine Gasteropodes	∵	∵	×	∵	∵	∵	×	∵	×	×	×	△	△	△	⊙
Fluviatile Acephala								∵	∵			×	×	×	⊙
Terrestrial and Fluviatile Gasteropodes									∵	∵	∵	△	△	△	⊙
Acetabuliferous Cephalopodes					∵	∵	×	∵	∵	∵	∵	∵	∵	∵	⊙
Tentaculiferous Cephalopodes	⊙	△	△	∵	∵	∵	∵	∵	△	×	△	∵	∵	∵	∵
Fishes	∵	∵	×	∵	∵	∵	×	∵	∵	∵	×	△	×	∵	⊙
Reptiles				∵	×	∵	△	∵	×	∵	∵	∵	×	×	⊙
Birds					?				∵		∵		∵	×	⊙
Mammalia							?					∵	∵	×	⊙

58. It appears that the creation of fishes, reptiles, birds, and mammalia, the four vertebrated classes, underwent a sudden and large augmentation at the epoch of transition from the tertiary to the human period, and that, to crown all, man appeared for the first time in the period to which he has given his name. Among the infinite variety of fossils discovered in the strata of the earth, there is no instance of human remains.

59. Although the various classes of animals and vegetables, when once called into existence, have continued to prevail upon the earth till the present time, the same is not true of the genera constituting these classes, and still less of the species of these genera, as already mentioned. Species appear in particular strata, no trace of which is found in any other, superior or inferior. The inference is, that such animals existed only during the period corresponding to the deposition of these particular strata.

It happens sometimes that particular species prevail through certain groups of strata, superposed in regular order, but totally disappear from all subsequent and antecedent. Such species are accordingly characteristic, not indeed of particular strata, but of those limited groups of strata in which they prevail, and the inference is, that they had continued to exist upon the earth during the period corresponding with the deposition of the groups, but did not exist there before or after.

60. The species which thus prevailed upon the earth during geological periods more or less limited, and which ceased to exist before the period marked by the presence of the human race, have accordingly supplied to the geologist tests for the identification of strata much more determinate than any which depend on their mineral constituents. When the presence of a particular species is strictly limited to particular strata, it becomes an unerring test of the presence of that stratum wherever this species is found. If it has prevailed through groups of strata, it is a test, though not of particular strata, still of the group to which its presence is limited.

61. Numerous examples of these characteristic species may be mentioned. A certain family of Crustacea, called TRILOBITES, are almost exclusively limited to the Silurian period, appearing rarely in the lower bed of the carboniferous limestone, and never above them.

62. The Trilobites consisted of an oblong body, divided transversely into three parts, and also longitudinally into the same

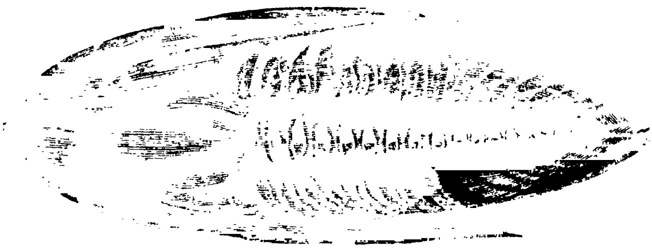


Fig. 6.—(Trilobite) Ogygia Guettardi.

number of lobes. The comparison of the forms of these animals with those of existing Crustacea, renders it probable that they dwelt in the depths of the sea, far from coasts, floating on their back, and never resting, inasmuch as their feet could not retain them stationary, and movement was necessary for their respiration. From a peculiarity of the mouth, it is inferred that they were carnivorous, preying probably on naked Mollusca or

Annelida, with which their remains are found associated. But one of the most interesting facts connected with them is the structure of their eyes, which resemble those of insects described in our Tract on "Microscopic Drawing." They consist of a vast number of minute lenses of octagonal form, set in the ends of tubes arranged side by side, so as to produce a radiating mass of eyes, enabling the animal to look at the same time in every direction. As many as four hundred of these lenses have been found set in a single cornea.

63. Such a structure proves, if proof were wanted, that the properties of light, and of the transparent media constituting the atmosphere and water, were, at the remote epochs when the earth was tenanted by those creatures, what they now are. "With respect to the waters," says Dr. Buckland, in reference to these creatures, "we conclude that they must have been pure and transparent enough to allow the passage of light to organs of vision, the nature of which is so fully disclosed by the state of perfection in which they are preserved. With regard to the atmosphere, also, we infer, that had it differed materially from its actual condition, it might have so far affected the rays of light that a corresponding difference from the eyes of existing Crustaceans would have been found in the organs on which the impressions of such rays were then received. Regarding light itself, also, we learn, from the resemblance of these most ancient organisations to existing eyes, that the mutual relations of light to the eye, and of the eye to light, were the same at the time when Crustaceans, endowed with the faculty of vision, were first placed at the bottom of the primeval seas, as at the present moment. Thus we find among the earliest organic remains, an optical instrument of most curious construction, adapted to produce vision of a peculiar kind, in the then existing representatives of one great class in the articulated division of the animal kingdom. We do not find this instrument passing onwards, as it were, through a series of experimental changes, from the more simple into more complex forms: it was created, at the very first, in the fulness of perfect adaptation to the use and condition of the class of creatures to which this kind of eye has ever been, and is still, appropriate. If we should discover a microscope, or telescope, in the hand of an Egyptian mummy, or beneath the ruins of Herculaneum, it would be impossible to deny that a knowledge of the principle of optics existed in the mind by which such an instrument had been contrived. The same inference follows, but with cumulative force, when we see nearly four hundred microscopic lenses set side by side in the compound eye of a fossil trilobite; and the weight of the argument is multiplied

a thousand-fold, when we look to the infinite variety of adaptations by which similar instruments have been modified, through endless genera and species, from the long-lost Trilobites of the transition strata, through the extinct Crustaceans, and the countless hosts of living insects. It appears impossible to resist the conclusions as to unity of design in a common Author, which are thus attested by such cumulative evidences of Creative Intelligence and Power; both as infinitely surpassing the most exalted faculties of the human mind, as the mechanisms of the natural world, when magnified by the highest microscopes, are found to transcend the most perfect productions of human art."

64. In like manner the lias, which is the earliest deposit of the Oolitic period, is characterised by various organic remains, as well of reptiles as of mollusca and the lower divisions. Among the latter may be mentioned a particular species of Ammonites, called the Ammonites Bucklandi, and among the former the ichthyosaurus,

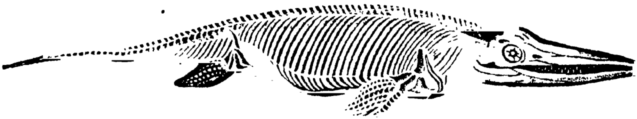


Fig. 7.—The Ichthyosaurus.

or fish-lizard, is an example of an extinct animal of this tribe, which has the muzzle and general aspect of a porpoise, the head of a lizard, the teeth of a crocodile, the vertebræ of a fish, the sternum or breast-bone of an ornithorhynchus, and the fins of a whale. The enormous magnitude of the eyeballs was one of the peculiarities of this genus. The cavities in which they were lodged, in one of the species, measured not less than fifteen inches in diameter. A ring of bony plates surrounded the socket, which apparently seemed to protrude more or less the globe of the eye, and vary the convexity of the cornea, so as to adapt the organ for near or distant vision. This, combined with the great power of the fins or propellers, must have conferred upon the reptile great promptitude in perceiving and seizing its prey.

These reptiles were essentially aquatic, and the form of their teeth proves them to have been carnivorous. Their coprolites, or fossilised excrements, show that their intestine was spirally arranged, like that of certain fishes.

65. The Wealden strata, lying near the upper part of the oolitic and the lower part of the cretaceous, is characterised by remains of the Monocotyledonous * division of plants, by ferns, by various

* Having only one seed-lobe.

tribes of the lower animals, by insects, fishes of the genus Lapidotus, and, among the colossal class of reptiles, by the Hylæosaurus, and among terrestrial quadrupeds, by the Iguanodon.

66. Among the numerous animals characteristic of the Cretaceous period may be mentioned the Mososaurus of Hoffman, the Belemnites mucronatus, the Terebratula plicatilis.

67. In cases where a group of strata is characterised by the prevalence of a particular family of fossils, which first appear at its

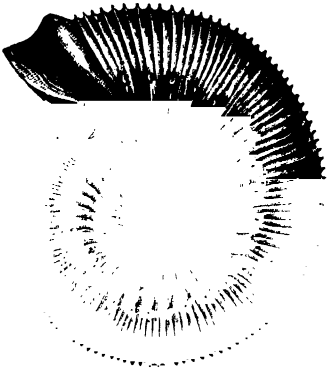


Fig. 8.—Ammonites Humpriasianus.

lowest, and finally disappear at its uppermost layer, the succeeding strata are often distinguishable one from another, by the prevalence in them of a different species of this generic family. Thus

Fig. 9.

Fig. 10.

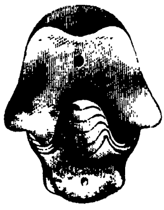
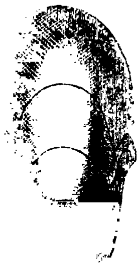


Fig. 11.



Nautilus Danians.

for example, the Ammonites, so called from their spiral form, resembling the horn sculptured on the head of Jupiter Ammon, commence in the Silurian and finally disappear after the chalk.

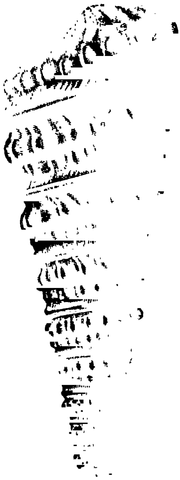
But each stratum, from that in which the family first appears

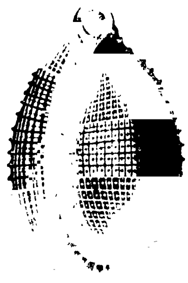
to that in which it disappears, is distinguished by the presence of a peculiar species. Of 222 species of Ammonites 17 belong to the oldest fossiliferous rocks, 7 to the carboniferous system, 15 to the new red sandstone, 137 to the oolite, and 47 to the chalk.

68. Among the organic remains characteristic of strata or groups of strata, the following examples may be mentioned: Fossil Cephalopodes are exceedingly numerous in the palæozoic group; but of all the genera hitherto discovered, one only, that of the nautilus, has come down to the present times.

These fossils appear in great numbers in the lower strata of the secondary rocks, are few in the lias and oolite groups, re-appear in great numbers again in the cretaceous, and nearly disappear from the tertiary rocks.

The examples are so numerous, and preserved in such perfection, that it is difficult to select any in preference to another, as illustrations of their forms. The nautilus, the only surviving genus of the Tentaculiferous Cephalopodes in the first periods of animal life, had nearly the form which it still retains.





. 13.—Cypræa Elegans

Fig. 12.—Murchisonia Bigranulosa.

69. Fossil Gasteropodes are, like the Cephalopodes, extremely numerous. The terrestrial and fluvial genera have in general appeared for the first time in the Tertiary period; but marine

genera have been found in all the rocks from the Silurian upwards, and in gradually increasing numbers. They were, therefore, among the earliest manifestations of animal life on the globe; and what is remarkable is, that most of the genera, including even those of the Silurian period, still survive.

The close analogy of these ancient forms with the existing species will be manifest, by some examples taken from among the countless numbers of fossil shells collected by geologists.

A fossil shell from the Permian group is shown in fig. 12, and one found in all the tertiary beds, in fig. 13.

One of the genera which first appears in the middle strata of

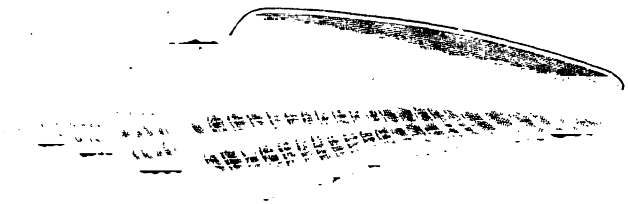


Fig. 14.—Voluta Egata.

the cretaceous group is shown in fig. 14, and one which begins in the middle of the oolite, in fig. 15.

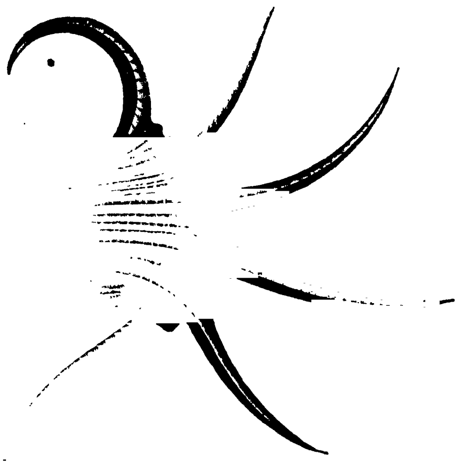


Fig. 15.—Pterocera Oceani.

Fig. 66.—BARREN ISLAND IN THE BAY OF BENGAL.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER III.

70. Spondylus.—71. Pentamerus.—72. Reticulipora.—73. Ceratites.—74. Enormous masses of animal remains forming entire islands and continents — Ehrenberg's discoveries.—75. Dr. Mantell's table of organic strata.—76. Forms of life in the Silurian period.—77. Sir R. Murchison's observations on the changes of the fórms of life from period to period.—78. Stratification in undisturbed plains horizontal.—79. Strata thrown into oblique positions by disruption of igneous rocks.— 80. Formation of mountains. — 81. Arrangement of strata on their flanks. — 82. Strata sometimes upheaved without being disrupted.— 83. Sometimes disrupted. — 84. Sedimentary strata deposited subsequently to disruption — discordant stratification. — 85. How these supply data for determining the epoch of the disruption.—86. Determination of the relative ages of mountains—Cumbrians and Grampians much older than the Alps.—87. How inclined strata have enabled geologists to analyse the structure of the terrestrial crust to the level of the igneous rocks.—88. Erosion of stratification by the action of water, and the subsequent deposition of other strata.—89. Basalts—their character and composition.—90. Various forms of basaltic rocks.—91. Their extensive diffusion over all parts of the earth.—92. Their columnar structure—Giant's Causeway.—93. Basaltic causeway of the Volant—Dykes and colonnade of Chenavari.—94. Veins of basalt.—95. Basalts in mounds.—96. Basaltic grottoes—Kase grotto of Bertrich-Baden—Fingal's Cave.—97. Trachytic rocks.—98. Trachytic mountains.—99. Their origin igneous.

70. The Spondylus, figs. 16, 17, of which there are forty-five

Fig. 16.

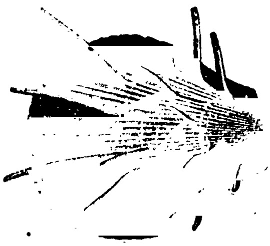


Fig. 17.

Spondylus Spinosus.

fossil species, first appears in the lowest stratum of the cretaceous group, and presents an example of the fossil Lamellibranchiæ.

71. The Pentamerus, figs. 18, 19, of which there are twenty-one fossil species, is an example of the Brachiopoda. This is

Fig. 18.

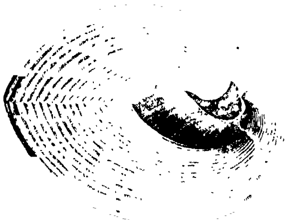


Fig. 19.

Pentamerus Knightii.

first seen in the lowest strata of the silurian group, and becomes extinct after the Devonian period, so that its existence was limited to the earliest epochs of animalisation.

72. The Reticulipora, figs. 20, 21, 22, 23, an example of the Bryozoares, is an extinct genus Retepora, of which there are five fossil species known; the first in the middle strata of the oolites, and the others in the upper strata of the cretaceous group. In this the meshes are formed of high vertical laminæ, supplied with cells by transverse lines on each side; fig. 20 shows the whole in its natural size; fig. 21, the external part magnified; fig. 22, the internal part magnified; fig. 23, the laminæ as shown with a still higher magnifying power.

73. The Ceratites belong to the family of the mollusca called Bacculine, the only known species of them found in the lowest strata of the cretaceous system.

Fig 20.

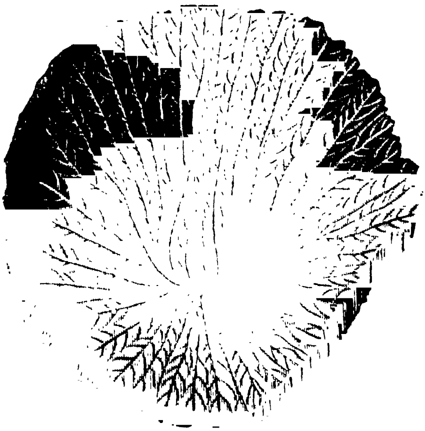
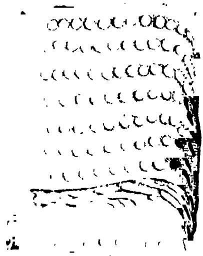


Fig. 22.



. 21.

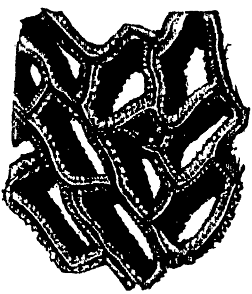
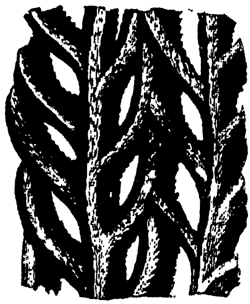


Fig. 23.



Reticulipora obliqua.

74. Among the most wonderful results of the animalisation of the earth, in the remote geological periods, is the enormous extent of matter which various species of animals elaborated from the gaseous or liquid element around them, by vital action, and which have remained as a perpetual record of their presence. Whole islands, and even continents, have been produced by the secretive functions and other vital agencies of countless myriads

of these living instruments. Ehrenberg, the celebrated Prussian microscopist and naturalist, mentions a stratum in Germany, not less than 14 feet in thickness, composed exclusively of the shells of animalcules, so minute that forty thousand millions of them would not fill a space greater than a cubic inch. Mountains, hundreds and even thousands of feet in height, are found to be composed exclusively of organic matter. The strata of vegetable origin are not less extensive, consisting of forests engulfed by the subsidence of vast tracts of land, or embedded in the mud of rivers and estuaries, of lignite and brown coal in the tertiary deposits, of coals and shales in the carboniferous strata, and of silicified and calcified trunks of trees in the tertiary and secondary formations.

Fig. 24.—Ceratites Nodosus.

75. But the strata which consist wholly or principally of animal remains are so numerous, and of such vast extent, that, as Dr. Mantell observed, the exclamation of the poet may be reiterated by the philosopher,

"Where is the dust that has not been alive?"

for there is not an atom in the superior strata of the crust of the globe that has not probably passed through the complex and marvellous laboratory of vitality.

The various families of animals from the infusoria and zoophytes, up to man himself, have then contributed more or less, by their organic remains, to form the solid crust of the globe. The following table, taken from the work of Dr. Mantell, presents a concise view of some of the most obvious examples of these remarkable deposits.

Rocks Composed wholly or partly of Animal Remains.

Strata.	Prevailing Organic Remains.	Formations.
Trilobite schist	Trilobites	Silurian system.
Dudley limestone	Corals, crinoidea, crustaceans, shells, &c.	"
Shelley limestone	Brachiopodous shells	"

TABLE OF FOSSIL MINERALS.

Rocks Composed wholly or partly of Animal Remains.		
Strata.	**Prevailing Organic Remains.**	**Formations.**
Mountain limestone .	Corals and shells . . .	Carboniferous system.
Encrinital marble . .	Crinoidea and shells . . .	,,
Mussel-band . .	Fresh water mussels . . .	,,
Ironstone nodules . .	Trilobites, insects, and shells .	,,
Lias-shales and clays .	Pentacrinites, reptiles, fishes . .	Lias.
Limestone . . .	Terebratulæ, and other shells .	,,
Lias conglomerates .	Fishes, shells, corals . . .	,,
Gryphite limestone .	Shells, principally gryphites .	,,
Shelley limestone .	Terebratulæ, and other shells . .	Inferior oolite.
Stonesfield slate . .	Shells, reptiles, fishes, insects .	Oolite.
Pappenheim schist . .	Crustacea, reptiles, fishes, insects	,,
Bath stone . .	Shells, corals, crinoidea, reptiles, fishes	,,
Ammonite limestone	Shells of cephalopoda, principally ammonites . . .	,,
Coral rag . . .	Corals, shells, echini, ammonites	,,
Bradford limestone .	Crinoidea, shells, corals, cephalopoda	,,
Portland oolite . .	Ammonites, trigoniæ, and other shells	,,
Purbeck and Sussex marble . .	Fresh water-shells and crustacea .	Wealden.
Wealden limestone	Cyclades and other fresh-water shells, crustacea, reptiles, fishes	,,
Tilgate grit (some beds)	Bones of reptiles, fishes, fresh-water shells	,,
Farringdon gravel . .	Sponges, corals, echini, and shells	Green sand.
Jasper and chert .	Shells	,,
Green sand . . .	Fibrous zoophytes	,,
Chalk . .	Polythalamia and other animalcules	Cretaceous.
Maestricht limestone	Corals, shells, ammonites, belemnites, and other cephalopoda, reptiles . . .	,,
Hippurite limestone .	Shells, principally hippurites . .	,,
Hard chalk (some beds)	Echini and belemnites . .	,,
Flints . .	Sponges and other fibrous zoophytes; infusoria, &c., echini, shells, corals, crinoidea . .	,,
Limestone . . .	Fresh-water shells . . .	Tertiary.
Nummulite rock .	Nummulites	,,
Septaria . .	Nautili, turritellæ, and other shells	,,
Calcaire grossier .	Shells and corals	,,
Gypseous limestone	Bones of mammalia (Palæotheria, &c.), birds, reptiles, fishes .	,,

Rocks Composed wholly or partly of Animal Remains.		
Strata.	Prevailing Organic Remains.	Formations.
Lacustrine marl . .	Cyprides, phryganea, fresh-water shells	Tertiary.
Monte Bolca limestone	Fishes	,,
Bone-breccia . . .	Mammalia, and land shells .	,,
Sub-Himalaya sandstone . . .	Bones of elephants, mastodons, reptiles, &c.	,,
Tripoli	Infusoria	,,
Semiopal . . .	Infusoria	,,
Richmond earth . .	Infusoria	,,
Guadaloupe limestone	Human bones, land shells, and corals	Human epoch.
Bermuda limestone .	Corals, shells, serpulæ, infusoria	,,
Bermuda chalk . .	Comminuted corals, shells, &c. .	,,
Bog iron ochre . .	Infusoria	,,
Siliceous limestone . .	. . . .	Tertiary.

Even in this list, extensive as it is, numerous strata in which animal remains largely predominate, have been omitted. In the tertiary and more recent deposits, every order of existing animated nature is found. The bones of man, however, are confined to the superficial part, which has been formed since the globe was peopled by the races which now inhabit it.

76. How completely changed the inhabitants of the earth have been from one geological period to another, may be inferred from the following observations of Sir R. Murchison. "Beginning," says he, "with the *vertebrata*, are not the fishes of the old red sandstone as distinct from those of the carboniferous system, on the one hand, as from those of the Silurian on the other? M. Agassiz has pronounced that they are so. Are any of the *crustaceans*, so numerous and well defined throughout the Silurian rocks, found also in the carboniferous strata? I venture to reply, not one. Are not the remarkable *Cephalopodus mollusca*, the *Phragmoceras*, and certain forms of *Lituites*, peculiar to the older Silurian system? Is there one species of the *Crinoidea* figured, known in the carboniferous strata? Has the *Serpuloides longissimus*, or have those singular bodies the *Graptolites*, or, in short, any zoophytes of the Silurian system been detected in the well-examined carboniferous rocks? And in regard to the corals, which are so abundant, that they absolutely form large reefs, is not Mr. Lonsdale, who has assiduously compared multitudes of specimens from both systems, of opinion, that there is not more than one species common to the two epochs?"

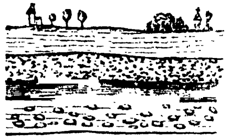
77. These anticipations of Sir R. Murchison have been more than realised by the subsequent researches of M. D'Orbigny, founded upon his own observations, which extended over a large portion of the New as well as of the Old world, and upon the entire mass of facts connected with the analysis of the crust of the earth collected by the observations of the most eminent geologists in all parts of the world. It appears from these researches, that during the long series of periods of geological time from the first appearance of organised life upon the globe, to the period in which the human race and the contemporaneous tribes were called into existence, the world was peopled by a series of animal and vegetable kingdoms, which were successively destroyed by violent convulsions of the crust, which produced as many devastating deluges. The remains of each of these ancient creations are deposited in a series of layers or strata one over the other; and from an examination of them it has been found that each successive animal kingdom was composed of its own peculiar species which did not appear in any posterior or succeeding creation, but that genera once created were frequently revived in succeeding periods; that many of these genera, however, became extinct long before the arrival of the human period; that during the human period no new genus was called into existence, except that of the human race, which, however, according to the idea of the most eminent naturalists, ought to be regarded as an order rather than a genus.

Each of the succeeding animal kingdoms which thus temporarily inhabited the earth consisted of many hundred species. Thus it has been ascertained by M. D'Orbigny, that there are deposited in the Cambrian or Lower Silurian strata not less than 418 species of the animals which inhabited the globe in the first period of its animalisation, and that these included specimens of all the principal divisions of animals from the Vertebrata downwards.

It will be sufficient, however, for the present, thus briefly to indicate these important discoveries, which we shall develop much more fully in the next volume of these series.

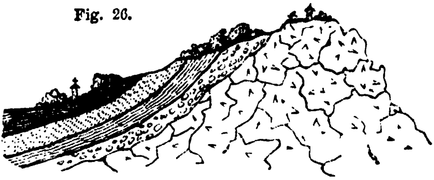
78. As already explained, the strata, when originally deposited, must in all cases have had a horizontal position, and they must succeed each other in their normal order, whenever the part of the earth at which they lie has undergone no disturbance subsequently to the date of their deposition, which has sometimes been the case with extensive plain countries. In such cases, therefore, a section of the crust would exhibit them in parallel and horizontal layers, as in fig. 25.

Fig. 25.



79. In undulating and mountainous countries it is found, however, that, instead of being horizontal, they are variously

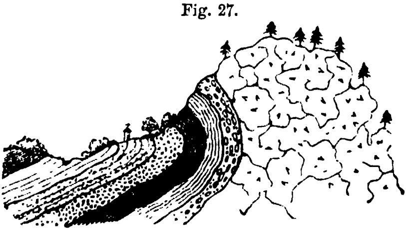
Fig. 26.



inclined (fig. 26), and sometimes bent into, or even beyond, the vertical direction (fig. 27).

When it is considered that at the time of their deposition the strata must have been horizontal, it will be evident that the position shown in these figures could only have been given to them by a force acting from below, by which they were heaved upwards, and by which the crust was broken, the igneous rocks having forced themselves through it.

Fig. 27.



80. In such cases hills or mountains of greater or less elevation are formed, at the summits of which the igneous rocks which have been protruded through the stratified crust are at the surface, and the edges of the strata thus broken are ranged along the flanks, the lowest or most ancient being nearest the summit, and the others succeeding each other in their proper order in descending towards the adjacent valley or plain.

81. It will be evident that the stratum whose edge is highest on the mountain is that which lies the lowest on the plain, and that whose edge is lowest on the mountain is that which is highest or nearest the surface on the plain.

82. In the cases here exhibited the igneous rocks have split the stratified crust and broken quite through it. This, however, is not always the case. It often happens that the uplifting force loses its energy before the superincumbent strata are cracked, in which case they would cover the elevation preserving the order of their superposition, but would be, as before, inclined in accordance with the declivity of the hill produced by the uplifting force.

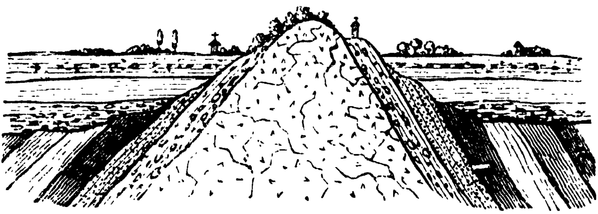
83. In other cases the superior strata, but not the inferior, are broken through, as shown in fig. 28. The edges of the disrupted

Fig. 28.

strata are then exposed upon the flanks of the elevation, and are ranged as above described; while the inferior strata, not disrupted retain their natural order upon the summit.

In other cases (fig. 29) the disruption is complete, and the

Fig. 29.



broken strata are ranged on each of the opposite declivities in the same order as already described.

84. It happens often that after the cessation of the disturbing force, by which the strata have been uplifted, the land having been again submerged, new depositions take place, the strata of which are of course horizontal and superposed upon those rendered oblique by the previous disturbance. This sort of superposition of strata is called by geologists discordant or unconformable stratification, and wherever it occurs it affords evidence of the action of a disturbing force from below, the geological date of which can be determined with more or less precision by a due examination and comparison of the superposed strata.

Cases of this kind of discordant stratification are shown in fig. 28 and fig. 29, in both of which horizontal strata deposited upon the oblique strata, are disposed along the slopes of the elevation.

85. It is evident that the epoch of the action of the disturbing force must, in all cases, have been posterior to that of the deposition of the inclined, that is, of the disturbed strata. It is equally apparent that the disturbing action must have ceased before the

deposition of the lowest of the superincumbent horizontal strata. The date of the disruption is therefore fixed geologically at some period between those of the deposition of the two strata just mentioned. Now whenever it so happens that the lowest, and, therefore, the first deposited of the horizontal strata, stands the next in order above the highest of the inclined strata in the geological scale, the date of the disruption is geologically fixed, being at the epoch between the deposition of two strata which follow each other in immediate succession.

But if, as often happens, the lowest of the horizontal strata hold a place in the geological scale separated from the highest of the inclined strata by several intermediate layers, which are locally absent, then the date of the catastrophe becomes more uncertain, inasmuch as it may have taken place at any epoch between those of the depositions of the highest of the inclined and the lowest of the horizontal strata.

86. Nothing is more beautiful or conclusive than the reasoning by which the geological dates of mountain-ranges have been determined by these means. One of the most interesting consequences resulting from the observation of such discordant stratifications as are here described, is the means they afford geologists of determining the relative ages of different ranges of mountains. Thus, for example, it is easily demonstrated that the mountains of Cumberland, Lammermuir, and the Grampians were raised above the surface of the ocean long before the Alps had burst the crust of the earth, and before even the continent of Europe was dry land. An examination of the slopes of these British ranges shows that the strata dislocated and inclined are those of the old slate and limestone, while the level strata superposed upon them in the adjacent plain are the more recent ones of the red sandstone. It follows that these ranges were raised above the waters posterior to the epoch of the deposition of the old slate and limestone, but antecedently to that of the red sandstone; and since the red sandstone has been deposited horizontally along their base, it follows that the land surrounding them was covered with water subsequently to their elevation.

An examination of the Alps gives a very different result. On the flanks of these mountains the tertiary strata are found inclined, sloping downwards, until they become level upon the general surface of Europe. It follows, therefore, that the date of the disruption to which the Alps owe their elevation was posterior to the deposition of the tertiary strata upon the European continent, while the elevation of the British ranges above mentioned was anterior to the deposition of the red sandstone; from which it follows that the Grampian, Lammermuir, and Cumbrian

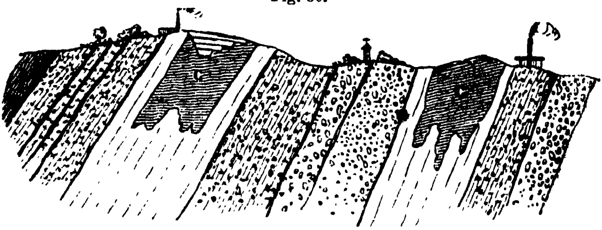
mountains were dry land, while the greater part of the continent of Europe was covered by the ancient ocean, and long before the Alps were reared above its surface.

In a subsequent tract this subject of the relative ages of the mountain system will be more fully developed.

87. From what has been here explained, and from inspection of figs. 26 to 29, the manner in which geologists have been enabled to analyse the crust of the earth to depths far exceeding any which could be reached by direct excavation, mining, or boring, will be easily understood. Nature herself, by these prodigious disruptions, has exposed to view the structure of the sedimentary strata in all cases where no subsequent deposition has taken place over them. By such disruptions it often happens that the strata are inclined over a large extent of country, the surface of which, intersecting their planes at a very oblique angle, is necessarily formed by the section of the strata in the order of their superposition, the breadth of the several sections being so much the greater, the more oblique the angle formed by the horizontal plane with the planes of the strata.

In fig. 30 the strata are represented inclined very slightly from

Fig. 30.

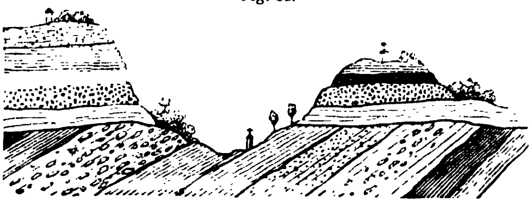


the perpendicular, and consequently the breadth of each stratum at the surface is very little greater than its actual thickness; but it will be easily understood that if the obliquity of the strata to a level plain were greater, a very thin stratum would present at the surface a considerable breadth. Supposing then the complete series of strata in any tract of country to be inclined at a very oblique angle to the level plain, it will be easily understood that in travelling in a direction at right angles to the lines of intersection of the strata with the surface, the succession of strata may be examined, and a much greater extent of their thickness submitted to observation, than could be accomplished by any artificial sections of horizontal strata.

88. Among the indications afforded by discordant stratifications of past convulsions to which the land has been subject, are some

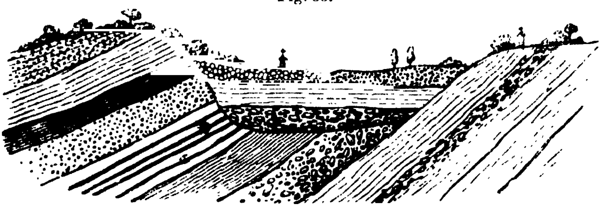
which show that, by the violent agitation of the waters consequent on sudden changes of level of their bed, and of the parts of continents over which they have swept, strata already formed have been partially broken up and carried away by currents. Excavations, such as that represented in fig. 32, are explained in this manner.

Fig. 32.



In such cases it has often happened that the waters under which such broken strata were submerged, having again become tranquil, a new series of strata have been deposited horizontally, filling up the excavation thus formed, as shown in fig. 33.

Fig. 33.



89. Closely allied with the matter ejected from volcanoes are the Basaltic deposits, which form so grand a feature in the scenery of many countries with which travellers are familiar.

All the circumstances and characters which attend these rocks conspire to show that they have issued from openings in the crust of the earth in a state of fusion much more complete than that of volcanic lava, and in the process of cooling have, in many cases, been crystallised, so as to assume those remarkable varieties of the columnar form, so conspicuously developed in the north of Ireland, the Scottish Islands, and many other parts of the world.

The Basaltic rocks are characterised by a dark colour and a compact base of the mineral called *Labradorite*, including black pyroxene, generally the magnetic oxide of iron, frequently peridote, and sometimes crystallised feldspar, to which they owe their porphyritic structure.

90. The fluid basalt often assumes the form of prismatic columns in the process of crystallisation, consequent upon slow cooling. Mr. Gregory Watt imitated this artificially by reducing 7 cwt. of Dudley basalt to fusion and causing it to cool slowly, when globular masses were formed, which gradually enlarged and pressed one against the other, until they forced themselves into regular columns, resembling in all respects those of natural basalt.

In some places basalt forms vast plateaux of considerable thickness, in others it is found in detached sheets of less extent, at points of mountains, more or less distant one from the other, and at the same level, as if it had originally been a single sheet and had been disrupted, by the convulsions of which the mountains have been the result.

In some cases the basalts form isolated masses or mounds rising in the midst of plains, altogether removed from all similar formations. They are also often found in veins in the strata of the earth, like those of minerals. They sometimes also present themselves as extensive walls, or in a series of separate mounds having a common direction. When basaltic rocks are presented in the form of sheets or mounds, the upper part is generally composed of porous cellular scoriform matter, irregularly divided, and terminated below by a plane surface, sensibly horizontal. When the mass is composed of several layers, these layers are separated one from another generally by thin beds of rapilli.*

91. Basaltic deposits are much more extensively scattered over the surface of the globe than those of ordinary volcanic origin. Unlike volcanic products, they are not confined to particular centres of action, but appear to have been produced wherever the terrestrial crust, yielding to the pressure from below, was rent so as to give issue to the fused matter. In the British Isles basaltic products are found in various places, and more particularly in the north of Ireland and Scotland. In France they are found everywhere from the northern part of Auvergne to Montpellier, and even to Toulon. On the borders of the Rhine they extend from the Ardennes to Cassel, and are continued eastward into Saxony, Bohemia, and the surrounding countries. They prevail to a great extent in Iceland, are recognised in the West India Islands and St. Helena, in the island of Ascension, and in almost all the islands of the southern ocean.

92. The tendency of these rocks to form themselves into prismatic columns has more especially excited the attention of the curious. In some cases all the prisms converge to the summit of

* Volcanic dust.

a mound, which thus assumes a sheaf-like structure. In others they take the form of close columns with the most picturesque aspect. In others again, these columns, cut off at a certain level, form a sort of mosaic pavement, to which the name of causeway has been given. Of this one of the most magnificent examples is presented in the case of the Giant's Causeway, in the north of Ireland.

93. Examples of similar formations are presented in different parts of Europe, and especially in the Vivarais, in the department of Ardèche, in France. A remarkable series of basaltic causeways is there presented on the banks of the river Volant, between Vals and Entraignes, a view of which is given in fig. 31, p. 33. The colonnades of Chenavari, near Rochemaure, fig. 34, and the dykes which are near the same place, fig. 35, present examples of other varieties of basaltic forms.

94. Basaltic rocks, having all the prismatic characteristics above described, are frequently presented in the form of mineral veins. Examples of this are found in the central parts of France, and also on the borders of the Rhine. Most commonly the matter composing the vein is compact or divided by irregular cleavage, but it also sometimes exhibits the prismatic form, the axis of the prisms being horizontal, fig. 36.

95. When basalts take the form of a mound, the lower part of the mass often presents a multitude of appendages which

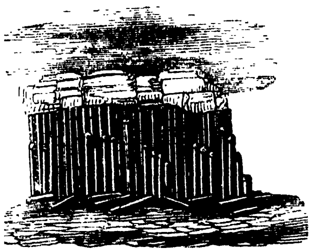


Fig. 34.—Colonnade of Chenavari, near Rochemaure.

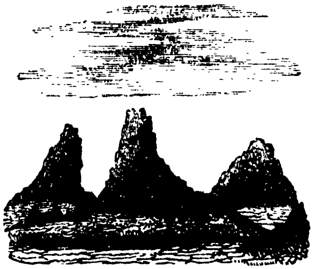


Fig. 35.—Dykes of Chenavari.

penetrate like roots into the subjacent earth; showing that the matter in a liquid state had flowed into the crevices, and moulded itself there. The earth thus in contact with the basaltic mass is often found calcined to a considerable depth, and the vegetable remains which it includes are carbonised. Examples of this are presented upon the cliffs of the plateau of

Mirrabel, in the Vivarais, descending towards St. Jean le Noir, fig. 38.

Fig. 36.

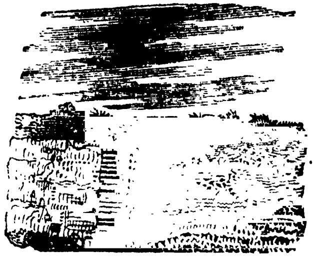
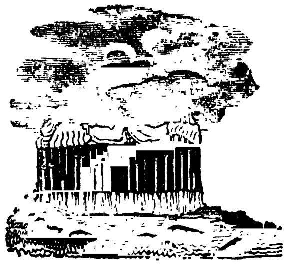


Fig. 38.



96. Grottoes, caves, and tunnels are often found in the midst of these basaltic masses, and in those of trap rocks, which have a close analogy to them. Examples of this may be seen in the Vivarais, on the borders of the Rhine, near Bertrich-Baden, between Trèves and Coblentz, where the columns forming the grotto consist of rounded blocks superposed, resembling a pile of cheeses, from whence the grotto has received the name of Kase Grotte, or Cheese Grotto, fig. 39. But by far the most magnificent of these basaltic grottoes is the celebrated Cave of Fingal, in the Island of Staffa, fig. 37, p. 49.

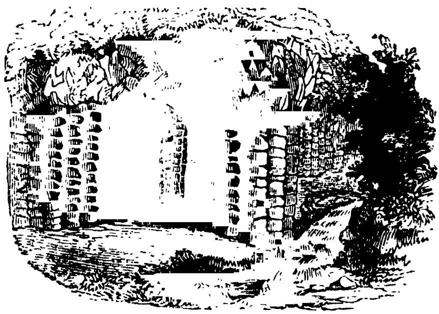


Fig. 39.—The Kase Grotto of Bertrich-Baden.

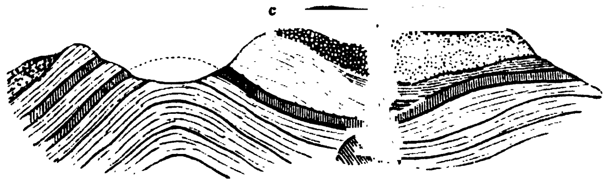
97. Another eruptive product of the terrestrial crust, still more extensive than the basalt, is the trachytic rocks, which form the celebrated Puy-de-dôme, in Auvergne, the Mont D'or, the Cantal,

the Mézenc, and the Mégal, upon the borders of the Velay and the Vivarais. They prevail also on the right bank of the Rhine, and the Siebengebirge. They form immense groups in Hungary and Transylvania, in the Caucasus, in Greece, where their continuation appears in the islands of Milo and Argentiera and extends to the centre of Santorin. They reappear in the Lipari Islands, in the Campania, in the Euganean mountains, in the Azores, in the Canaries, in South America, where the loftiest heights of the Cordilleras are composed of them, in Central Asia, and in many of the islands extending along its coast to Kamschatka.

98. The trachytic formation presents itself not only in isolated mounds, narrow bands, and sheets scattered over the surface of the globe like those of the basalt, but also in vast mountains, generally assembled in large groups, forming the most elevated masses and covered with terrific asperities. Their flanks are torn by precipitous valleys and deep gorges.

99. The matter composing these vast accumulations was evidently ejected from the bowels of the earth by the disruption of the crust, issuing in a state of pasty fusion through the opening thus made in the superjacent stratified rocks, fig. 40.

Fig. 40.



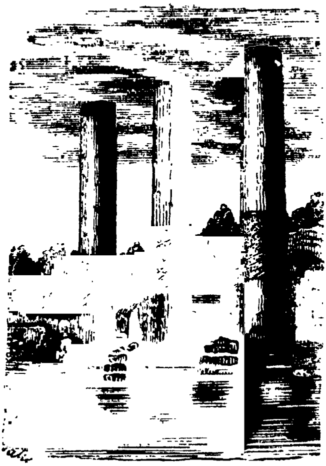


Fig. 52.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER IV.

100. Elie De Beaumont's explanation of the formation of mountain chains —101. Effects of the earthquake of 1838 in South America.—102. Inference as to the probable effects of the vast earthquakes which produced the great mountain ranges.—103. Dislocations in parallel directions produced parallel chains.—104. Origin of mineral veins explained.—105. Veins are found in groups—generally parallel. —106. Deposition of rock-salt in cavities of Muschelkalk.—107. Natural agencies still manifested are sufficient to explain all geological phenomena.—108. Internal fluidity of the earth—109. Effects of internal heat on the surface.—Why the climates of the higher latitudes at former epochs were similar to those of the tropics at present—explanation of the presence of tropical fossils in polar latitudes.—110. The undulations and disruptions assumed by geologists as physical causes still proceed, though with less energy.—111. Effects of earthquakes—that of Calabria, 1783.—112. Effects in Sicily.—113. Earthquakes at Chili.—114. Earthquake of 1819 in India.—115. Like phenomena recorded in all ages and countries.—116. Similar phenomena traditional—island of Atlantis.—117. Permanency of the sea-level proves the undulations of the land.—118. Undulations of the Swedish peninsula.—119. Similar changes in Greenland, and in the Indian archipelago.—120. General sinking of South America.—121. Singular

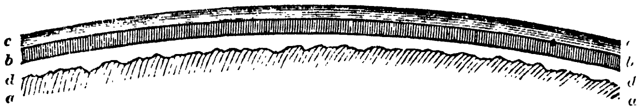
example of a submerged forest on the western coast of America.—122. Temple of Jupiter Serapis.—123. Historical researches of Professor Forbes.—124. Tradition of a submerged city under Lough Neagh.—125. Why these undulations of the earth's crust might be expected.—126. Effects of disruption of the crust.—127. Volcanic eruptions of 1808 in the Azores.—128. The Monte Nuovo.

100. THE formation of cracks and fissures in the crust of the globe has been ingeniously explained by M. Elie de Beaumont, as the natural and necessary consequence of the process of superficial cooling taking place upon a globular mass of matter in a state of fusion.

To render intelligible the reasoning and theory of this eminent geologist and naturalist, let us suppose the globe, as we have formerly described it, to have been originally in a state of igneous fusion, and to undergo a gradual superficial cooling, by which a thin solid shell would be formed upon it. The contraction of this shell, taking place from its inner towards its outer surface, would leave a vacant space between the central mass in fusion and the concave interior surface of the solid shell. Supposing also, as we have formerly explained, that after the external surface had fallen below the temperature which maintains water in a state of vapour, the atmospheric vapours, being condensed, had fallen in rain; the external surface of the terrestrial spheroid would then have been covered with an ocean of uniform depth and would consequently have been totally destitute of land.

An imaginary section of a part of the terrestrial crust in this state is represented in fig. 41, where *b* is the solid crust, *a* the liquid central mass, *d* the intermediate vacant space, and *c* the ocean of uniform depth covering the entire surface.

Fig. 41.



But the state of equilibrium which would maintain this state of things could not continue. The internal fluid matter would press more or less upon the thin crust surrounding it, which being unequal in its structure, would offer proportionately unequal resistance, and consequently yielding at its weakest points would be dislocated as shown in fig. 42, the fragments being thrown into infinitely various positions. Thus the piece *f* being tilted obliquely, would be raised at one end above the surface of the ocean, depressed at the other. It would, therefore, form a chain of

mountains with a gentle declivity on one side, and abrupt precipices on the other, such as the Pyrenees and the Andes. In other places the two parts fractured would form gentle declivities on both sides,

Fig. 42.

as at *h*. The matter in fusion within the crust forcing its passage upwards in the opening between them would be solidified by the process of cooling on arriving above them. Thus chains of mountains would be formed of moderate declivities on both sides, having igneous rocks at their summits.

In fine, some fragments, such as *e*, would remain nearly level, and would be pushed above the surface, in which case they would form extensive plains of dry land, or might remain below it, in which case they would form the bottom of a shallow sea.

Thus we may understand in its most literal sense the brief description of the formation of the earth in the sacred records: "God divided the land from the water, and saw that it was good."

Such dislocations of the terrestrial crust would not be confined to a single catastrophe, but would from time to time be reproduced. According as, by the continued process of cooling, the solid crust of the earth became thicker and thicker, a vacant space would still be produced between its inner surface and the central fluid matter, and like consequences would from time to time ensue, so that the history of the earth would consist of a series of convulsions by which its crust would from age to age be disrupted, new chains of mountains being formed, and new continents being raised above the waters of the ocean and former ones submerged. Movements of the waters would necessarily attend each such convulsion, compared with which the most violent oceanic commotion with which we are familiar is tranquillity itself.

101. It is related that the earthquake of 1838, which took place at Chili, in South America, although it did not change the level of the continent by more than a few feet, produced effects at the enormous distance of 4000 miles, extending even to the islands of Oceania. The earthquake on the coast of Peru laid in ruins all the towns along the shore. At the moment of the shock, the waters of the ocean, raised with violence, were poured upon the coast, carrying with them an immense mass of sand and shingles,

and transporting vessels of the largest tonnage to a distance of four miles inland.

102. When such effects arise from a change of the surface not exceeding a few feet in elevation, it may be imagined what prodigious deluges must have been produced when the Alps and Pyrenees were raised to their present altitude from the ordinary level of the earth's surface, or when the chain of the Andes was elevated by a dislocation, which must have extended over nearly 3000 miles of the earth's surface.

It cannot then be doubted that the consequence of such convulsions would be universal; and some idea may be formed of the extraordinary ravages which the frightful deluges consequent upon them would occasion upon the surface of the earth, especially at the moment when all levels of land and sea were changed in consequence of the dislocation which caused them, and when a considerable mass of sediment still in a movable state was transported by the torrents of the ocean. It will not be considered extraordinary, that all the terrestrial animals should be at once destroyed by the immediate action of the waters, while the marine animals would suffer equal destruction by the violent transport of the terrestrial matter swept among them.

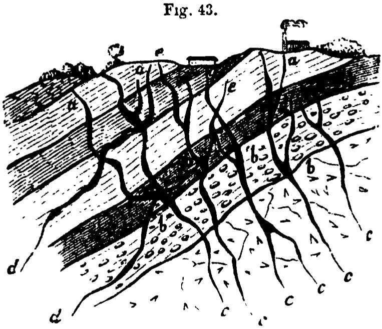
103. M. Elie de Beaumont has shown that these movements of terrestrial dislocation have never been partial, but that each of them has been produced along lines, having one uniform direction, as may be seen in the case of the Pyrenees, of certain ranges of the Alps, and upon a still greater scale in the case of the Andes and the Himalayas. We shall show more fully hereafter that the parallel lines of mountains have been raised at the same epoch, and that the succession of convulsions by which the ranges of mountains having different directions were produced, can be determined, and their geological dates assigned with more or less precision.

104. The circumstances which have been explained, attending the past history of the earth, have also produced cracks and fissures in its crust, through which the central liquid matter has been forced, and in which it has been solidified, forming veins of mineral matter different altogether from the strata which they intersect. These veins often contain earthy matter, such as carbonate of lime, sulphate of baryta, and quartz, in which case they offer but little interest. They are, however, more frequently filled, either wholly or partially, with metalliferous substances, in which case they acquire great importance. These metalliferous veins are generally found either in the igneous or in the most ancient of the stratified rocks.

105. It is rare that a single vein is met with. Most commonly

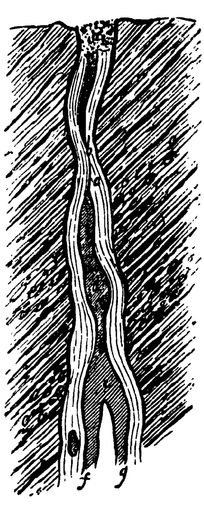
great numbers prevail in the same system of strata, and generally take a direction nearly parallel. Fig. 43 shows a transverse section of such a system. The similarity of the mineral matter which fills them demonstrates their common origin. It often happens that one system of such veins is intersected by another, presenting mineral contents totally different from the former. These are called *cross veins*. It is rare that a vein is completely filled with metalliferous matter. Most commonly, these substances form threads, *a*, *b*, *c*, *d*, *e*, *f*, *g*, fig. 44, more or less irregular, included in the middle of the stony crystalline matter which fills the vein. The thickness of the metalliferous thread varies at different parts of the vein; at some points it is considerable, and at others becomes very small, often vanishing altogether.

Fig. 43.



106. Numerous cavities are often formed in the midst of stratified rocks, probably by the dissolving action of the subterraneous waters. Such cavities, which are met with in all the sedimentary strata, are generally filled after their formation with new substances totally different from the surrounding rock. It is thus that masses of rock-salt are found in the Muschel-kalk and in the Marnes Irisées, fig. 45.

Fig. 44.

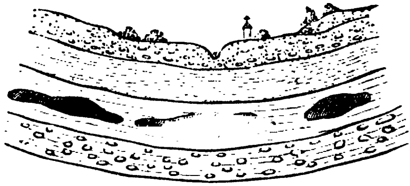


Similar masses of carbonate of zinc, as formed in the upper part of a stratum of transition limestone, are shown at C C, in fig. 30.

107. Since the memorable revolution effected by Bacon in the conduct of physical inquiries, a maxim has been universally admitted and adopted, in virtue of which, in the formation

of hypotheses for the explanation of natural phenomena, no cause can be admitted, except such as can be shown to have real existence, and which, being admitted, shall appear to be sufficient to produce the phenomena which it is put forward to explain. In accordance with this rule, geologists are therefore required to show

Fig 45.



that the elevated internal temperature of the globe, those upheavings and disruptions of land, those sedimentary deposits from water, those ejections of fluid and pasty matter from clefts and caverns, those abrasions of the solid crust by the corroding action of water, and its modifications by the action of the atmosphere, are severally real agencies still in visible operation, and producing effects similar in kind though different in degree from those ascribed to them in geology, and also that even the difference in degree, which must be admitted to be often very considerable, admits of satisfactory explanation.

Before, therefore, proceeding further in the exposition of the phenomena disclosed by the labours of geologists, we shall here pause for the purpose of showing the reality of the various physical causes to which geologists have ascribed the phenomena. We shall see that like phenomena have been, and still are, developed on the surface of the earth; and that the reasons why these agencies were more energetic at remote epochs than at present are sufficiently obvious.

108. It has been already very fully explained in our Tract on "Terrestrial Heat," that in descending deeper and deeper through the crust of the globe, the temperature continually rises; so that at a depth which forms a very insignificant fraction of the semi-diameter of the globe, the materials which constitute it must have a temperature altogether incompatible with their continuance in the solid state,—a temperature, in short, which is above the point of fusion of the most refractory of these materials.

109. The superficial heat of the earth may be considered, therefore, to result from the combined effects of solar and internal heat. In the present condition of the globe, the effects of the

former are incomparably greater than of the latter; but it may be imagined that at earlier epochs, when the solid crust of the earth was much less thick, the internal heat produced upon the surface a much more powerful effect; so that the climates of all parts of the globe must have been much more elevated than at present. Numerous effects compatible with this reasoning have been discovered by the researches of geologists. Thus, the organic remains of animals and plants found in the sedimentary strata deposited at earlier epochs in the growth of the globe, are such only as could have lived in climates of a much more elevated temperature, than those which now characterise the latitudes in which they are found. Thus, the fauna and the flora (terms adopted by naturalists to express the entire collection of animals and plants existing in any place) prevailing in high latitudes at remote epochs, were such as could exist at present only within the tropics.

110. The alternate upheavings, depressions, disruptions, and dislocations of the crust of the earth assumed by geologists in their explanation of the phenomena are still exhibited, though

Fig. 46.

Fig. 47.

on a much smaller scale, in the phenomena attending earthquakes. These effects have been so fully explained in our Tract on "Earthquakes and Volcanoes," that little need be added to what has been there stated. As these phenomena are manifested at present, they are most frequently more or less local, though sometimes their effects are spread over little less than an entire hemisphere. The earthquake which took place in the island of Ischia, on the 2nd of February, 1828, was not felt in the slightest degree either in the neighbouring isles or upon the Continent; while that of New Grenada, which took place on the 17th of June, 1826, exercised its influence over many thousand square miles. The earthquake which commenced in Lisbon in 1755, and which has been fully described in a former Tract, extended in one direction to Lapland, and in the other to Mar-

tinique. It was sensible, also, at right angles to this direction, from Greenland to Africa, where the cities of Morocco, Fez, and Mequinez were destroyed by it. Its effects were manifested in all parts of Europe at the same moment.

111. These convulsions not only destroy entire cities and overturn the most solid edifices, but they are attended with important modifications in the levels of the ground. Those of Calabria, in 1783, supply remarkable examples of them, and are so much the more worthy of attention, as they were circumstantially described by several eminent men who were witnesses of the phenomenon, such as Vicencia, physician of the King of Naples, Grimaldi, Sir W. Hamilton, and by a commission of the Royal Academy of Naples. The whole extent of the country was convulsed, the beds of the rivers were changed, houses were, some raised above the general level, and others at short distances from them sunk below it; edifices of the greatest solidity were cracked in their walls, while certain parts of them were raised above others, and their foundations in many instances forced above the earth; crevices were formed in the ground, some of which measured five or six hundred feet in width; some were straight, some bifurcated; sometimes a single enormous cleft having a certain direction was intersected at right angles by a number of others, fig. 46; others were developed in clefts radiating from a centre, like a broken pane of glass, fig. 47. Some crevices laid open at the moment of a shock, and into which entire buildings had fallen, closed almost immediately again, crushing between their sides all that they had thus engulfed. In some cases the sides of the cleft were separated at the surface, but brought into contact with each other at a certain depth, figs. 48-9. In other cases, the parts disrupted merely sunk below the other without ceasing to be in contact, fig. 50.

Fig. 48.

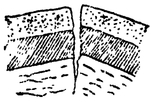


Fig. 49.

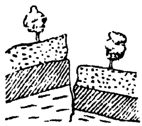
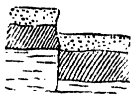


Fig. 50.

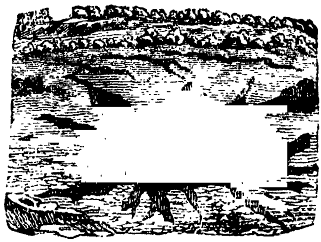


In other cases, the force which burst the superior crust was sufficient, not merely to split it into different clefts, but to produce in it a vast cavity, from the edges of which clefts diverged, fig. 51.

In some cases a considerable tract of ground was suddenly engulfed, carrying with it the plantations and buildings which

chanced to be upon it, and leaving nothing but a yawning gulf, with sides nearly vertical, from 300 to 400 feet deep. In some instances an immense quantity of water was collected in the cavities, and formed lakes more or less considerable in magnitude, some of which had no apparent issue, while the water from others flowed in enormous torrents. In other cases the contrary effects were manifested, rivers and lakes suddenly disappearing as if they had sunk into the bowels of the earth.

Fig. 51.



112. While the principal of these earthquakes upon the Italian peninsula was limited to the tract between Oppida and Soriano, the phenomena were propagated under the straits of Messina to that city, more than half of which, with twenty-nine surrounding towns and villages, was swallowed up. The bottom of the sea sunk, the shores were torn by clefts, and all the ground along the harbour of Messina was inclined towards the sea, sinking suddenly to the depth of some feet. The entire promontory by which the entrance to the harbour was formed, was swallowed up in an instant.

113. The earthquakes which took place on the coast of Chili in 1822—35—37, produced effects not less remarkable. Different parts of the coast from Valdivia to Valparaiso, an extent of more than 200 leagues, was manifestly raised above the water, as well as several adjacent islands extending to that of Juan Fernandez. The bottom of the sea, to a considerable distance, was similarly affected. Upon the coasts, rocks formerly covered with water, were raised eight or ten feet above the level of the sea, covered with the shells attached to them. Rivers, which emptied themselves at different parts of the coast, and which were navigable to vessels of small tonnage, became fordable. At sea, well known anchorages were diminished in depth; and various parts, where vessels formerly passed safely, were now complete shoals, inaccessible to vessels except those of the lightest draught.

114. Similar effects were manifested in India in 1819. A hill, 60 miles long, and 18 wide, extending from S.E. to N.W., was raised in the middle of a flat country, barring the course of the Indus. Further south, and in a parallel direction, the ground was sunk and with it the town and fort of Sindré, which remained, however, standing, though half submerged. The eastern embouchure

of the river became deeper at several places, and different parts of its bed, formerly fordable, ceased to be so.

115. In the records of all ages and countries, effects of the same kind are recorded. Large crevices in the earth have been formed, deep gulfs opened, into which cities, and even whole countries, have sometimes been swallowed up. From these openings, mephitic vapours, water in enormous quantities, sometimes cold, sometimes warm, have been ejected, and, occasionally, even flame has issued. Plains have been suddenly transformed into mountains, shoals produced in the deepest seas, mountains cracked and overturned, and mountainous tracts, many hundred miles in extent, suddenly levelled or replaced by deep lakes; rivers, turned from their beds, have discharged their waters into cavities thus formed; lakes, breaking through their banks, have been emptied, and their bottoms left dry, or have been turned through subterraneous openings suddenly formed beneath them. On the contrary, in some cases numerous springs, natural artesian wells, have been formed, supplying waters which suddenly issued from crevices of the rock or from tunnels. Thermal springs have been suddenly rendered cold, or altogether dried up, while others, on the contrary, have been produced where none existed.

All these, and many other phenomena, indicate the existence of internal convulsions, by which the matter subjacent to the crust of the earth is driven upwards through its crevices.

116. Independently of the phenomena of this class which are authentically recorded in history, many others are subjects of tradition. Thus, Pliny relates a tradition that Sicily had been separated from Italy, Cyprus from Syria, and Eubœa from Bœotia, by earthquakes. According to another classical tradition, a great island called Atlantis existed in ancient times west of the Straits of Gibraltar, having a numerous population. Its princes invaded Africa and Europe, but were defeated by the Athenians and their allies. Its inhabitants afterwards became wicked and impious, and the island was visited with the vengeance of the Gods, and swallowed up by the ocean in a single day and night. This legend is given by Plato, and is said to have been related to Solon by the Egyptian priests. According to all the analogies supplied by the phenomena described above, there is nothing impossible, or even improbable, in that part of this legend which refers to an island being engulfed by the ocean.

117. The cases in which the dry land has been invaded by the sea, or the bed of the sea left dry by the retirement of the waters, has been popularly, and even by the scientific of former days, ascribed to the change in the level of the waters of the ocean, their elevation producing inundations, and their fall leaving

tracts, formerly covered, dry. Considering the solid and apparently permanent character of the land on the one hand, and the *extreme mobility* of water on the other, such a conclusion was natural, and almost inevitable, until clear evidence of the contrary was obtained. It has, however, been proved that the very reverse has been the case of such phenomena, the mobility appertaining to the land, and the permanence to the sea. It has been shown, by observations made upon the level of the ocean, that it has not suffered any general change within historic times; but, on the contrary, that the cases in which the land has been inundated by the ocean must be ascribed to the sinking of the land, and those in which the waters have deserted their bed to the rising of the bottom of the sea.

118. These changes in the level of the crust of the earth have been in some cases sudden, as when they are produced by earthquakes, but in others they have been so gradual that they could only be ascertained by observation extending over long intervals of time. It had been long observed in different parts of Sweden, that the level of the surrounding ocean was subject to an apparent but slow and gradual change, in some places rising, in others falling. The Academy of Upsal, in 1731, commenced a series of observations with a view of determining the fact whether this apparent change of the ocean were real, or whether it were not caused by an actual change in level of the land. Marks were accordingly cut upon the faces of rocks at the level of the sea, and at the end of some years these marks were several inches above that level, from whence it was in the first instance inferred that the Baltic had suffered a depression of its level, so as to leave more or less of the bottom dry. These observations, however, being continued and multiplied, it was soon rendered apparent that, while the level of the Baltic remained unchanged, the phenomena were produced by actual changes in the level of the land. It was found that the apparent depression of the level of the ocean was different in different places, and that in some places, on the contrary, it appeared to have been even raised. Thus, while at certain points the apparent depression amounted to several inches, in others it did not exceed a fraction of an inch; at some places, such as the coast near Christianstad, the level of the sea appeared to be elevated. The conclusion deduced from all these observations was, that the apparent change of level of the sea was produced by a slow and gradual upheaving of the land in some places, and a sinking in others; that in Finland, and in a great part of Sweden, the surface was gradually raised without any perceptible shock, while in the southern parts of the peninsula a corresponding depression was produced.

119. Similar swellings and depressions of the land have been manifested elsewhere. Thus, for four centuries, the western coast of Greenland has been continually sinking through an extent of 600 miles north and south. Ancient buildings, as well upon the low islands of the coast as upon the mainland, have been gradually submerged, and the removal to considerable distances inland of various establishments which formerly existed upon the coast, has been rendered necessary. Similar sinkings of the surface have been manifested in certain islands of the Southern Ocean, especially in the Indian Archipelago.

120. It would even appear, from a comparison of the observations of Messrs. Boussingault and Humboldt, separated by an interval of thirty years, that the whole continent of South America is gradually sinking, and, if this process be continued, at some distant epoch it may even be submerged. The observations* referred to show that the altitudes of the Andes at the epoch of the observations of Boussingault were less than those given by the anterior observations of Humboldt; and these results are confirmed by the fact that the snow-line in this range of mountains has, in the interval referred to, apparently risen.

121. An interesting modern example of the subsidence of a considerable tract of country, clothed with forests, the trees remaining erect, although submerged beneath a river which still flows over them, is described by a late American writer, and will serve to illustrate these remarks. The whole district, from the Rocky Mountains on the east, and the Pacific Ocean on the west, and from Queen Charlotte's Island on the north, to California on the south, presents one vast tract of volcanic formation. Basalt—both columnar, and in amorphous masses, veins, and dykes—everywhere occurs, and craters of extinct volcanoes are still visible. Elevations and dislocations of the strata have taken place on an immense scale; and successive beds of basalt, amygdaloidal trap, and breccia, prove the alternation of igneous action and periods of repose. Within a few miles of the falls of the river Columbia, and extending upwards of twenty miles, trees are seen standing in their natural position, in a depth of water from 20 to 30 feet. The trees reach to high or fresh-water mark, which is 15 feet above the lowest level of the tide; but they do not project beyond the freshet rise, above which their tops are decayed and gone. In many places the trees are so numerous, that "we had to pick our way with the canoe, as through a forest. The water of the river was so clear, that the position of the trees could be distinctly seen, down to their spreading roots, and they are standing as in their natural state, before the country had become

submerged. Their undisturbed position proves that the subsidence must have taken place in a tranquil manner." *

122. Another most interesting and remarkable example of the alternate elevation and depression of the surface of the earth, manifested within historic times, is presented in the case of the ground upon which the temple of Jupiter Serapis stands, at Pozzuoli, near Naples. These ruins, standing on the northern shore of the Bay of Baiæ, at a short distance from the Solfatara, consist of the remains of a large building of quadrangular form, 70 feet in diameter, the roof of which was originally supported by 46 columns, 24 of which were granite, and 22 marble, each column consisting of a single stone. Many of these pillars are broken, and their fragments strewn about the pavement, but three of them still remain standing (fig. 52). Their base is near the level of the sea. The surface of the columns, the tallest of which is 42 feet in height, is smooth up to an elevation of 12 feet from the pedestal, where a band of perforations 9 feet wide commences, made by a species of mussel, called the *Modiola lithophaga*, which could only have lived in sea-water. Above this band, at the height of 21 feet from the pedestal, these cavities are discontinued, and the remainder of the pillars are smooth, like the lower part. The cavities, many of which still contain shells, sand, and microscopic shields, are of elongated elliptical shapes, and so numerous and deep as to prove that the pillars must have been submerged in sea-water to a height more or less above the limit of these borings, for a long period of time. The lower part of the columns, which are not similarly affected, must have been protected, while they were submerged, from the depredations of these boring mussels by surrounding accumulations of rubbish and tufa, while the upper parts projected above the water, and were consequently beyond the reach of these animals.

The platform of the temple is now about one foot below high-water mark, and the sea, which is only 40 yards distant, penetrates the intervening soil. The upper part of the band of perforation is at least 23 feet above the level of the sea.

It appears from all this, that the ground on which the temple stands must have changed its level more than once, being alternately heaved upwards and downwards. It is clear that when the temple was built, the ground of its foundation must not only have been high and dry, but remote from the shores of the bay, and at some subsequent period must have sunk gradually, and so

* Journal of an Exploring Tour beyond the Rocky Mountains, by the Rev. Samuel Parker, A.M. New York, 1838.

tranquilly as not to overturn the columns, to a depth above the band of perforation, and at a still more recent period must have again been raised to its present level.

123. It results from the researches of Professor Forbes upon this subject, that historical evidence is extant illustrating the respective dates of these changes of level. From inscriptions recording the embellishment of the temple by Septimius Severus (A.D. 193—211), and Marcus Aurelius (A.D. 161—180), it appears that the building was still entire, and occupied its present position at the close of the second and commencement of the third century; that in A.D. 1198, the eruption of the volcanic lake of Solfatara took place, attended with earthquakes, and a general subsidence of the coast ensued, which caused the temple to sink to a depth which submerged its columns in water to a height above the band of perforations. In this state it appears to have continued until the commencement of the sixteenth century; for the flat district called La Starza, in which the building stands, is described by contemporary observers as being covered by the sea in 1530. Eight years later, frequent and violent earthquakes prevailed along all that part of the Neapolitan coast; and on the 29th of September in that year, the volcanic eruptions burst forth which threw up the Monte Nuovo already described. During this catastrophe the coast on the north of the Bay of Baiæ was permanently raised 20 feet, forming a tract 600 feet in breadth, and including the area in which—

> "Those lonely columns stand sublime,
> Flinging their shadows from on high,
> Like dials, which the wizard Time
> Had raised to count his ages by!"—MOORE.

These were accordingly left above the water, several of the columns still retaining their original position. They seem to have been wholly neglected by antiquaries till 1750, when the shrubs and weeds with which they were overgrown and concealed were removed, and the earth accumulated in the court of the temple cleared away. For the last thirty or forty years a slow subsidence of the coast appears to have been going on, and the floor of the temple is often submerged.*

124. We are not informed whether the Irish tradition, reproduced by Moore so beautifully in the following lines, has been verified by any scientific observers; but, if so, it would seem as

* See a paper by Professor Forbes on the subject in Brewster's "Journal of Science," vol. i. second series; and also a letter quoted by Dr. Mantell, and addressed to him by M. Hullmandel, "Wonders of Geology," vol. i. p. 458.

though Lough Neagh were the result of a post-Adamite sinking of the ground.

> "On Lough Neagh's banks as the fisherman strays,
> When the clear cold eve's declining,
> He sees the round towers of other days
> In the wave beneath him shining!
>
> Thus shall memory, often, in dreams sublime,
> Catch a glimpse of the days that are over;
> Thus, sighing, look through the waves of time
> For the long faded glories they cover!"—MOORE.

125. It appears, then, that the crust of the earth, instead of being endowed with that character of stability and immobility popularly ascribed to it, is subject to incessant as well as occasional upheavings and depressions. It may indeed be regarded as in a certain degree elastic, yielding to the undulations, whether slow and gradual, or sudden and more violent, of the agencies within it.

Such phenomena, however, will cease to astonish when we reflect what an enormous disproportion exists between the thickness of the solid crust of the globe, and the mass of matter in a state of igneous fusion which it encloses; the crust being relatively thinner than a piece of card-board attached to the rind of an orange, it cannot be matter of surprise that it should be subject to more or less derangement of form, and even occasional disruption, by the action of the fluid matter within it. That such changes and such disruptions and their consequences should be much more considerable at earlier than at more recent epochs, is also a natural consequence of the growth of the crust of the globe by the process of cooling. The earlier the epoch the thinner that crust must have been, and the less its resistance to internal force. Forces which would now fail to produce any sensible effect upon its form, would at those earlier epochs have been sufficient to disrupt it. That such effects have been actually produced at various geological epochs is proved by the most incontrovertible evidence presented by the crust of the globe itself, as will presently be more fully explained. Volcanic phenomena are closely connected with those of earthquakes, and, like them, supply analogies by which various geological phenomena are explained.

126. When the crust of the earth is disrupted in the manner explained above, openings are made in it which supply communication between its internal fluid nucleus and its external surface, and through these openings matter of various forms is often ejected with vast force. The matter thus ejected consists sometimes of the disrupted and broken parts of the crust itself, which are projected upwards, vertically or obliquely as the case may be,

and often scattered over the surrounding country to vast distances. Sometimes the matter thus thrown up is in a state of pasty fusion, and is incandescent, scoriaceous, and pumiceous. In this semi-fluid state it is projected sometimes to a distance, and sometimes it flows in streams along the slopes of declivities, or collects in a sheet or layer of more or less thickness round the crater from which it is ejected.

127. These volcanic phenomena have been already, in part, explained in our Tract on Earthquakes and Volcanoes, but their connection with the condition and history of the crust of the earth is so close, and the aids they afford for the explanation of geological phenomena so important, that it will be necessary here further to enlarge upon them.

In the month of May, 1808, the ground in the island of San Jorge, one of the Azores, in the midst of an open plain and cultivated fields, was suddenly upheaved, after which it cracked at several places with a terrific noise. A vast cavity or crater was formed in the middle of it, having an area of nearly thirty acres, and surrounded within the distance of three miles by from twelve to fifteen smaller craters. An enormous quantity of scoriaceous and pumiceous matter was projected from it which covered the surrounding ground to the depth of five feet for an extent of twelve miles in length by three in breadth. Streams of molten matter issued from it, which continued to flow for more than three weeks from the principal crater to the sea.

128. The Monte Nuovo, which was formed upon the Neapolitan coast in the Bay of Baiæ in 1538, presents an example of like phenomena. A violent earthquake had prevailed for two years, which, on the 27th and 28th of September, 1538, suddenly increased so as to be attended with incessant movement of the ground day and night. The plain extending between the Lake of Averno (the ancient Avernus), the Monte Barbaro and the sea was then suddenly upheaved, and various crevices were formed in it; the ground, rising still more, assumed the form of a mountain. During the succeeding night, the summit of this mountain opened with prodigious noise, and vomited great masses of flame, accompanied by pumice stones and ashes. The eruption continued for seven days, the matter ejected filling up the Lucrine Lake. Since this eruption the most perfect tranquillity has continued at this place.

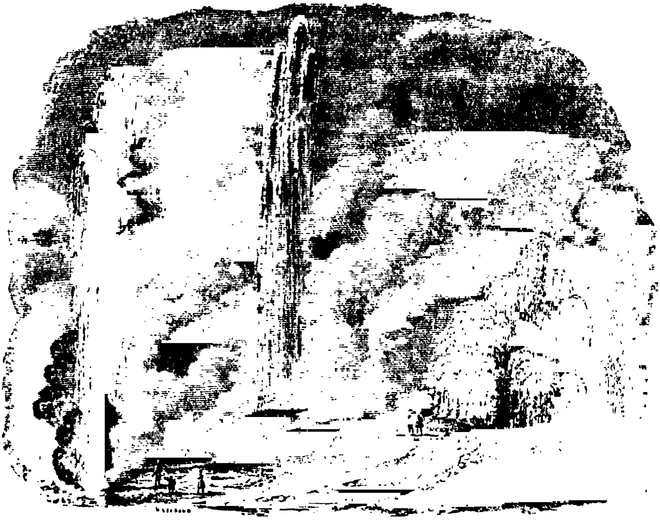


Fig. 71.—THE GEYSERS, ICELAND.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER V.

129. Volcanoes of the Andes—Pichincha, Cotopaxi, and Tunguragua.—130. Mexican volcanoes—Orizaba, Popocatapetl, Jorullo, and Colima. 131. Singular circumstances attending the elevation of Jorullo.—132. Ancient state of Vesuvius, according to Strabo—Eruption of 76 A.D.—Destruction of Herculaneum and Pompeii.—133. Volcano of Kiraueca in Owhyhee—Mr. Ellis's account of it.—134. Visit of Mr. Stewart and Lord Byron to it in 1825—Mr. Stewart's account of it.—135. Illustrations of the ejection of lava through the strata.—136. Effect of obstruction—formation of lateral craters.—137. Submarine eruptions—Formation of volcanic islands.—138. Volcanic islands off Santorin, in the Grecian Archipelago.—139. Phenomena attending the formation of such islands.—140. Craters of elevation.—141. Stratification around these craters—Island of Palma.—142. Formation of islands not necessarily preceded by eruptions.—143. Mount Etna.—144. Historical accounts of its eruptions.—145. Eruption of 1832.—146. The

Val del Bove.—147. Section and plan of Ætna.—148. Volcanic lakes. —149. Crescent form of volcanic islands.—150. Craters of elevation, temporary and permanent.—151. Barren island in the Bay of Bengal. —152. Traditional volcanic origin of Santorin.

129. THE famous volcano of Jorullo in the Anahuac mountains in Mexico had its origin in similar phenomena. The elevated plateau which forms the province of Quito, in South America, has been the theatre of extraordinary volcanic phenomena. Beneath it is a focus of volcanic energy, the channels of which communicate with the atmosphere by the craters of the great volcanoes of Pichincha, Cotopaxi, and Tunguragua, part of the chain of the Andes. These, by their groupings as well as by their lofty elevation and grand outlines, present the most sublime and picturesque aspect which is anywhere concentrated within so small a space in a volcanic landscape. The extremities of the chain are connected by subterranean communications; and this fact, which experience has made known to us in numerous instances, reminds us of the old and just statement of Seneca, that the crater is only the issue of more deeply-seated volcanic forces.

130. The Mexican volcanoes of Orizaba, Popocatapetl, Jorullo, and Colima also appear to be connected with each other, being placed in the direction of a line running transverse to the former, and passing east and west from sea to sea.

131. As was first observed by Humboldt, these mountains are all situated between north latitude 18° 59′ and 19° 12′. In an

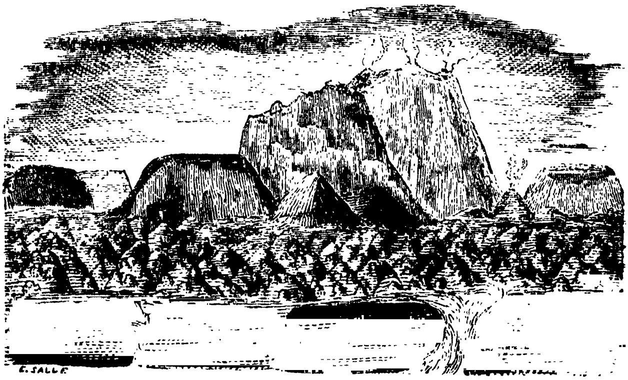


Fig. 53.—Volcano of Jorullo, Mexico.

exact line of direction with the other volcanoes, and over the same transverse fissure, Jorullo was suddenly elevated on the

29th of September, 1759. The circumstances attending the production of this volcano are so remarkable, that we shall here notice them in some detail.*

An extensive plain, called the Malpays, was covered by rich fields of cotton, sugar-cane, and indigo, irrigated by streams, and bounded by basaltic mountains, the nearest active volcano being at the distance of eighty miles. This district, situated at an elevation of about 2600 feet above the level of the sea, was celebrated for its beauty and extreme fertility. In June, 1759, alarming subterranean sounds were heard, and these were accompanied by frequent earthquakes, which were succeeded by others for several weeks, to the great consternation of the neighbouring inhabitants. In September tranquillity appeared to be re-established, when, in the night of the 28th, the subterranean noise was again heard, and part of the plain of Malpays, from three to four miles in diameter, rose up like a mass of viscid fluid, in the shape of a bladder or dome, to a height of nearly 1700 feet; flames issued forth, fragments of red-hot stones were thrown to prodigious heights, and, through a thick cloud of ashes, illumined by volcanic fire, the softened surface of the earth was seen to swell up like an agitated sea. A huge cone, above 500 feet high, with five smaller conical mounds, suddenly appeared, and thousands of lesser cones (called by the natives *hornitos*, or ovens,) issued forth from the upraised plain. These consisted of clay intermingled with decomposed basalt, each cone being a *fumarolle*, or gaseous vent, from which issued thick vapour. The central cone of Jorullo is still burning, and on one side has thrown up an immense quantity of scoriaceous and basaltic lavas, containing fragments of primitive rocks. Two streams, of the temperature of 186° of Fahrenheit, have since burst through the argillaceous vault of the hornitos, and now flow into the neighbouring plains. For many years after the first eruption, the plains of Jorullo were uninhabitable from the intense heat that prevailed.†

132. It appears that the cone from which Vesuvius takes its present character has been the result of similar effects.

In the description of the mountain given by Strabo, no mention whatever is made of the cone which now forms its most remarkable feature. The slopes of the mountain, says Strabo, were regions of the greatest fertility; its summit was truncated, entirely sterile, and had a burnt aspect, displaying cavities full of crevices and calcined stones, from which it must be conjectured that they had been formerly volcanic craters. It seems, therefore, that the cone to which the name of Vesuvius now more

* Cosmos, vol. i. p. 229. Trans.

† Mantell, p. 837.

properly belongs, and of which all the products differ altogether from the rocks of the semicircle called the *Somma* which existed in ancient times, was not formed until a much more recent period, and probably dates from the famous eruption of the year 76 A.D., which was signalised by the loss of Pliny. It was then, probably,

Fig. 54.—Vesuvius as now formed.

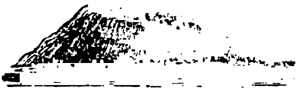


Fig. 55.—Vesuvius in the time of Strabo.

that a permanent communication was opened between the crater and the internal parts of the earth. This catastrophe appears to have produced but little lava, although it was attended with violent effects on the surrounding country, throwing a great part of the mountain into the sea, and burying Herculaneum and Pompeii, not, as is vulgarly supposed, under molten matter ejected from the crater, but under avalanches of pumiceous substance, which existed previously upon the slopes of the mountain.

133. Of all existing volcanoes, that of Kirauea, in Hawaii, one of the Sandwich Islands, better known under the popular name of Owhyhee, and noted as the theatre of the murder of Captain Cook, exhibits volcanic phenomena under their most sublime and imposing aspect. The island of Hawaii, which is about seventy miles long, and covers an area of 4000 square miles, is a complete mass of volcanic matter, perforated by innumerable craters. It is, in fact, a hollow cone, rising to an altitude of 16000 feet, having numerous vents over a vast incandescent mass, which doubtless extends beneath the bed of the ocean, the island forming a pyramidal funnel from the fluid nucleus beneath to the atmosphere. The following graphic account of a visit to the crater, by Mr. Ellis, affords a striking picture of the splendid, but awful, spectacle which this volcano presents.

"After travelling over extensive plains and climbing rugged steeps, all bearing testimony of igneous origin, the crater of Kirauea suddenly burst upon our view. We found ourselves upon the edge of a steep precipice, with a vast plain before us fifteen or sixteen miles in circumference, and sunk from two to four hundred feet below its original level. The surface of this plain was uneven, and strewed over with large stones and volcanic rocks; and in the centre of it was the great crater, at the distance of a mile and a half from the precipice on which we were standing, We proceeded to the northern end of the ridge, where, the sides being less steep, a descent to the plain below seemed practicable;

but it required the greatest caution, as the stones and fragments of rocks frequently gave way under our feet, and rolled down from above. The steep which we had descended was formed of volcanic matter, consisting apparently of light red and grey vesicular lava, lying in horizontal beds, varying in thickness from one to forty feet. In a few places the different masses were rent in perpendicular and oblique directions, from top to bottom, either by earthquakes, or by other violent convulsions of the ground. After walking some distance over the plain, which in several places sounded hollow beneath our feet, we came to the edge of the great crater. Before us yawned an immense gulf in the form of a crescent, about two miles in length from the north-east to south-west, one mile in width, and 800 feet deep. The bottom was covered with lava, and the south-west and northern parts were one vast flood of burning matter. Fifty-one conical islands of varied form and size, containing as many craters, rose either round the edge or from the surface of the burning lake. Twenty-two constantly emitted either columns of grey smoke or pyramids of brilliant flame, and at the same time vomited from their ignited mouths streams of lava, which rolled in blazing torrents down their black indented sides into the boiling mass below. The existence of these conical craters led us to conclude that the boiling cauldron of lava did not form the focus of the volcano, but that this liquid mass was comparatively shallow, and the basin which contained it separated by a stratum of solid matter from the great volcanic abyss, which constantly poured out its melted contents through these numerous craters into this upper reservoir. We were further inclined to this opinion from the vast columns of vapour continually ascending from the chasms in the vicinity of the sulphur banks and pools of water, for they must have been produced by other fire than that which caused the ebullition in the lava at the bottom of the great crater; and also by noticing a number of small vents in vigorous action high up the sides of the great gulf, and apparently quite detached from it. The streams of lava which they emitted rolled down into the lake, and mingled with the melted mass, which, though thrown up by different apertures, had perhaps been originally fused in one vast furnace. The sides of the gulf before us, although composed of different beds of ancient lava, were perpendicular for about 400 feet, and rose from a wide horizontal ledge of solid black lava, of irregular width but extending completely round. Beneath this ledge the sides sloped gradually towards the burning lake, which was, as nearly as we could judge, three or four hundred feet lower. It was evident that the large crater had been recently filled with liquid lava up to this ledge, and had, by some subterranean

channel, emptied itself into the sea, or upon the low land on the shore; and in all probability this evacuation had caused the inundation of the Kapapala coast, which took place, as we afterwards learned, about three weeks prior to our visit. The grey, and in some places apparently calcined sides of the great crater before us—the fissures which intersected the surface of the plain on which we were standing—the long banks of sulphur on the opposite sides of the abyss—the vigorous action of the numerous small craters on its borders—the dense columns of vapour and smoke that rose out of it, at the north and south ends of the plain, together with the ridge of steep rocks by which it was surrounded, rising 300 or 400 feet in perpendicular height—presented an immense volcanic panorama, the effect of which was greatly augmented by the constant roaring of the vast furnaces below." *

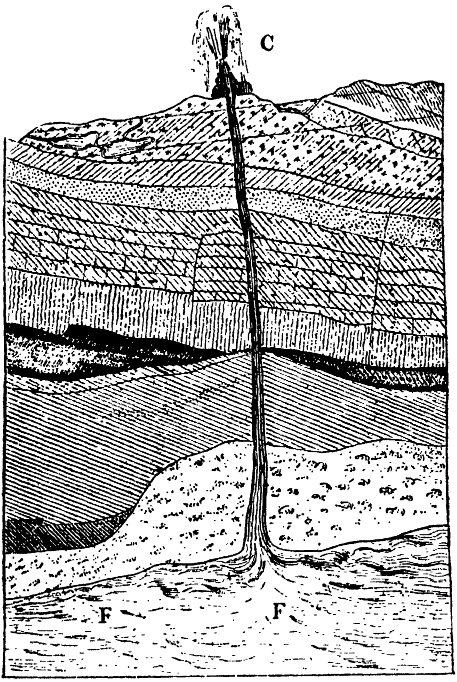
134. This volcano was also visited in 1825 by Mr. Stewart, accompanied by Lord Byron and a party from the "Blonde" frigate, who descended to the bottom of the crater. Mr. Stewart has left the following description of it:—"The general aspect of the crater," observes he, "may be compared to that which the Otsego Lake would present, if the ice with which it is covered in winter were suddenly broken up by a heavy storm, and as suddenly frozen again, while large slabs and blocks were still toppling, and dashing and heaping against each other, with the motion of the waves. At midnight the volcano suddenly began roaring, and labouring with redoubled activity, and the confusion of noises was prodigiously great. The sounds were not fixed or confined to one place, but rolled from one end of the crater to the other; sometimes seeming to be immediately under us, when a sensible tremor of the ground on which we lay took place; and then again rushing on to the farthest end with incalculable velocity. Almost at the same instant a dense column of heavy black smoke was seen rising from the crater directly in front, the subterranean struggle ceased, and immediately after flames burst from a large cone, near which we had been in the morning, and which then appeared to have been long inactive. Red-hot stones, cinders, and ashes, were also propelled to a great height with immense violence; and shortly after, the molten lava came boiling up, and flowed down the sides of the cone and over the surrounding scoriæ, in most beautiful curved streams, glittering with a brilliancy quite indescribable. At the same time, a whole lake of fire opened in a more distant part. This could not have been less than two miles in circumference, and its aspect was more horribly

* Ellis's Polynesian Researches, vol. iv.

sublime than anything I ever imagined to exist, even in the ideal visions of unearthly things. Its surface had all the agitation of the ocean; billow after billow tossed its monstrous bosom into the air, and occasionally those from different directions burst with such violence, as in the concussion to dash the fiery spray forty or fifty feet high. It was at once the most splendid and fearful of spectacles."

135. The manner in which the liquefied matter is driven upwards through the superjacent crust of the earth, and ejected from the crater is illustrated in fig. 56, where F F represents

Fig. 56.



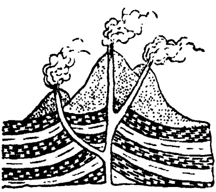
the fluid nucleus of the globe, and F C the passage along which the fluid matter has burst its way through the successive strata to the crater from which it issues.

136. It sometimes happens that the passage, through which it is thus forced in the first instance becomes obstructed, so

that the escape of the lava through it is intercepted. In such cases the pressure of the fluid matter acting against the walls of the cleft, or channel, breaks through them at one or more points of least resistance, and new issues are formed on another side of the original crater. These lateral craters may also be produced, even though the central crater is still in activity (fig. 57).

137. Volcanic eruptions are not confined to the land, but are often produced in the bed of the ocean. In such cases islands often rise suddenly out of the bottom of the deep. Thus, in 1831, the island of Julia arose in the Mediterranean, about 30 miles to the south-west of Sicily. Bogoslaw appeared in like manner, in 1814, in the Aleutinian Archipelago; Sabrina and another among the Azores, in 1811; besides various others around Iceland, in the Indian Archipelago, the Philippines, the Moluccas, and off the coast of Kamtschatka. One of the most remarkable examples of these was presented in the case of the island which rose above the waters, in 1796, at 30 miles from the northern point of Unalaska, one of the Aleutinian islands. A column of smoke was first seen to rise out of the sea. This was followed by the appearance of a black point at the surface of the water, from the summit of which blades of flame and incandescent matter were launched with violence. These phenomena continued for several months, during which the island increased greatly in magnitude and height. Afterwards, smoke alone issued from it, which, after continuing four years, ceased. The island nevertheless, still continued to increase in magnitude and height, without manifesting volcanic phenomena. In 1806, it had so augmented that it formed a cone, which could be perceived from Unalaska, upon which were formed four other smaller cones in the north-west side.

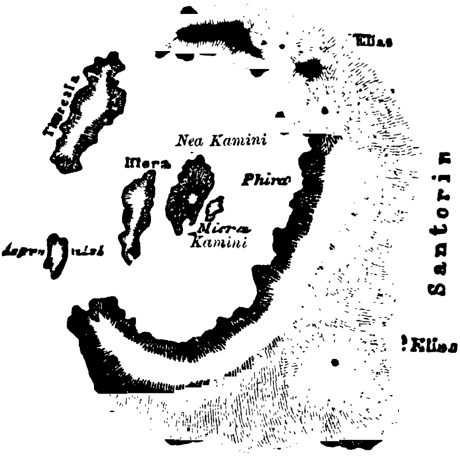
Fig. 57.



138. Some remarkable examples of submarine eruptions have been presented from the most remote times, in the Mediterranean and the Levant. According to ancient historians, the bay included between the islands of Santorin and Theresia (fig. 58), in the Grecian Archipelago, has been the special theatre of these phenomena. The island of Santorin is a half-moon-shaped tract of land, evidently of volcanic origin, and the islands of Theresia and Aspronisi, extending between the horns of the crescent, enclose the bay. Within this enclosure, the island of Hiera rose above the water in 186 B.C., and round it, and close to its coast several islets appeared in 19 A.D., 726 A.D., and 1427 A.D. In

1573 A.D., appeared the large island called Micra Kamini, and in 1707, the still larger one, Nea Kamini. The latter underwent a gradual increase of magnitude during several succeeding years.

Fig. 58.



No volcanic crater was formed upon these islands, which appear to cover the orifices in the subjacent crust through which the liquid matter which forced them up acted.

139. These submarine volcanic phenomena are generally preceded by incandescent matter thrown above the waters, by scoriaceous and pumiceous matter appearing on the surface, by burning rocks which appear in the midst of vaporous waves, and by the ebullition of the sea, the temperature of which then becomes very elevated. All these effects were manifested in modern times in the appearance of the islands of Julia, Sabrina, and others, and the more ancient phenomena are similarly described in historic narratives.

The circumstances attending them, however, are not always identical. Sometimes no solid rock is raised above the water. Thus, for example, at Kamtschatka, in 1737, jets of vapour only were thrown up. Great ebullitions of the sea took place, and pumiceous matter flowed on the surface. On the subsidence of the eruptions, it was found that chains of submarine mountains had been formed where previously there was a depth of 100 fathoms. In other cases there are not even jets of vapour, and the phenomenon is manifested only by the increased temperature

of the waters, and by the sudden elevation of the matter which existed at the bottom of the sea. This took place in 1820 at the island of Banda in the Moluccas, where the bay, which previously had a depth of 50 fathoms, was elevated by the tranquil upheaving of compact basaltic matter which previously existed there, and which formed a promontory composed of large blocks piled one upon the other, without any accessory phenomena except the increased temperature of the waters.

It has been ascertained also that violent submarine eruptions are often followed by slow and gradual upheavings of the bottom of the sea. This effect was manifested in the case of the island near Unalaska, and also in those produced near Santorin. It may be added also, that the islands thus produced are not always permanent; many of them disappear after intervals of more or less duration, being either swept away by the water or sinking into abysses formed under them.

140. Volcanic craters, which result from the upheaving of the crust of the earth in places where no volcano previously existed, are distinguished by the name of CRATERS OF ELEVATION, from those craters which break out at different points in existing volcanoes. In like manner, the conical mounds similarly formed are called cones of elevation. Craters of elevation are distinguishable even in places where no record or tradition of eruption exists, by the arrangement of the strata elevated, which is altogether dissimilar from what is found elsewhere. These strata are always inclined in all directions round the axis of the cone, as shown in fig. 59, presenting their edges abruptly towards the centre of the cavity. The Monte Nuovo, already mentioned, presents an example of this upon a small scale. The same formation is presented in the case of the semicircular Somma of Vesuvius.

141. Another characteristic, not less important, and especially useful for geological purposes in cases where the matter elevated is not stratified, is supplied in all great craters of elevation by the crevasses which extend from the borders of the crater to the external base of the mountain, and which are presented in so remarkable a manner in the Canaries, where they are called Barancos. These radiating crevasses are admirably shown upon the plan of the island of Palma, one of the Canaries, drawn by M. de Buch.

Fig. 59.

One of these Barancos, much deeper than the others, extends from the foot of the mountain, at a place called Tazacorte, to the base of the crater, as shown in the plan, and which is rendered still more apparent in the perspective view shown in fig. 61.

The volcanic islands which have arisen out of the ocean have assumed forms, all of which are analogous to those here described.

Fig. 60.—Plan of the island of Palma, one of the Canaries.

Thus for example, the island of Sabrina, at the moment of its

Fig. 61.—Perspective view of Palma.

appearance, took the form of a crater which had an opening to

the south, and which was terminated by crevasses from which boiling-water issued.

142. Although the crater-formed cavities which are so frequently observed at various parts of the surface of the earth have been in many cases preceded by volcanic eruptions, they are not invariably to be ascribed to that cause, and indeed in many cases there is abundant evidence that no such eruption could have taken place at the moment of their formation. We have already explained how the upheaving of the crust of the earth, produced by an earthquake shock, can produce not only radiating clefts, as in fig. 47, but also an open cavity, as in fig. 51, the edges of which are surrounded by divergent clefts.

143. Mount Etna, the most remarkable of European volcanoes, situated on the island of Sicily, and composed entirely of erupted mineral substances, rises to a height above the level of the Mediterranean of nearly eleven thousand feet. The circumference of its base is more than a hundred and eighty miles, and on a clear day it may be distinctly seen from any elevated point of the island of Malta, a distance of a hundred and fifty miles. Compared with this volcano, Vesuvius is insignificant. While the streams of lava from the latter never exceed seven miles in length, those of Etna very often are from fifteen to thirty miles, being five miles in breadth, and from fifty to a hundred feet in thickness. The surface of Etna presents three distinct regions. Around the base for an extent of twelve miles, the country is richly cultivated, and abounds in vineyards and pastures, and is the site of many towns, monasteries, and villages. The middle or temperate zone above is covered with forests of oak and chestnut, and a luxuriant vegetation reaches to within a mile of the summit. Above this all is sterility and desolation, and the highest point of the mountain is covered with eternal snow. The crater is about a quarter of a mile in height, and three-quarters of a mile in circumference, and is situated in the centre of a gently inclined plain, three miles in diameter. From the crater a column of vapour constantly issues, emanating from the mass of incandescent mineral matter which fills up the interior, and may be seen, in a state of ebullition, in the fumarolles in some of the lateral crevices, of which there are generally several accessible.

144. Etna is recorded as having been in a state of activity before the Trojan war; and ever since, at varying intervals, violent eruptions have occurred. In an eruption of 1669, the torrent of lava inundated a space of fourteen miles in length, and four in breadth, burying beneath it five thousand villas and other habitations, with part of the city of Catania, and at length falling into the sea. During several months before the lava burst

out, the old mouth, or great crater, was observed to send forth more smoke and flame than usual, and the top fell in, so that the cone became much lowered.

In 1809, twelve new craters opened, about half-way down the mountain, and threw out rivers of burning lava, by which several estates and farms were covered to the depth of thirty or forty feet; and in 1811, other vents appeared on the eastern side, and discharged torrents of liquid lava with amazing force.

145. In 1832, a violent paroxysm took place, and continued with but little intermission for several weeks. On the 31st of October, in the middle of the night, there arose, without any previous indication, a column of smoke and flame from the base of the large cone on the northern side; and, shortly after, an immense quantity of fluid matter was discharged from the crater, on the western side, divided into numerous streams. Next morning, repeated earthquakes, the increased noise of the lava, which now flowed rapidly, and the immense volumes of thick black smoke at the foot of Monte Scavo, announced that the eruption had greatly increased in violence, and several streams of lava were seen descending. On the 2nd of November, contrary to all expectation, the eruption ceased, and the lava was found to be so far cooled, that several adventurous observers were enabled to get upon it, and walk a few paces. On the 3rd, the hope that the fire was almost extinct was nearly certain; but in the evening, a violent earthquake, followed by several others less violent, with an increased quantity of smoke, foreboded an eruption; and two hours before midnight, another severe shock occurred, and was succeeded by black smoke mingled with flames, and incessant thunder.

"Having approached," says Signor di Luca, "as nearly as was prudent, to the hollow from which the fire issued, we found four apertures, which threw out burning matter. Raising our eyes from these vents, we observed a cleft or rent, about a mile in length, from which volumes of smoke arose from time to time; and, as at the bottom it reached the openings above-mentioned, it enabled us to behold the burning furnace in the interior of the mountain. Meanwhile the thunder was incessant, and the detonations were terrible; the lava continued to flow, and enormous masses of red hot substances were thrown to a great height mingled with vast volumes of flame and smoke. The shocks of earthquake were likewise so violent, that horses and other animals fled in terror from the places where they were feeding."

146. But by far the most interesting feature of Etna is an immense depression or excavation on the eastern side of the mountain, called the *Val del Bove*. This vast plain, or rather circular hollow, is five miles in diameter, and from two to three thousand

feet in the height of its bounding precipices, which in most places are nearly perpendicular. This remarkable area appears to have resulted from the giving way and subsidence of part of the crust of the volcano, from some violent action in the interior, which occasioned the sudden removal of an enormous mass of mineral matter. This plain is encircled by subordinate volcanic mountains, some of which are covered by forests, while others are bare and arid like many of the cones of Auvergne. The walls or cliffs surrounding this depression are formed of successive layers of lava of variable thickness, with interposed beds of tufa, ashes, and igneous conglomerates of different colours and degrees of fineness. They slope downwards towards the sea at an angle of from twenty to thirty degrees, and have evidently been formed at various intervals by successive eruptions from the top of the mountain, and were continuous before the subsidence took place which gives this region its present character.

The perpendicular sides of this natural amphitheatre are everywhere marked by vertical walls or dykes, which not only intersect the concentric sheets of lava and tufa, but, standing out in bold relief, like prodigious buttresses, impart a most extraordinary character to the scene; the greater induration of these intruded dykes having enabled them to resist the denuding action which has removed the less coherent pre-existing erupted materials. These buttresses are from two to twenty feet in thickness, and being of immense height, are extremely picturesque; some of them are composed of trachyte, and others of blue compact basalt with olivine. The surface of the plain is wild and desolate in the extreme, presenting the appearance of a tempestuous sea of liquid lava, suddenly congealed. Innumerable currents of lava are seen piled one upon the other, some of which terminate abruptly, while others have extended across the Val, and descended in cascades into the lower fertile regions, where they are spread out in sterile tracts amid the vineyards and orange groves.*

147. A section of Mount Etna, extending north and south between Catania on the south, and Taorminia on the north, is

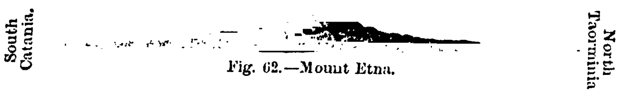


Fig. 62.—Mount Etna.

shown in fig. 62; the east, upon the slope of which the cavity in question is observable, being presented to the observer.

* See Captain Basil Hall's graphic description of a visit to the Val del Bove, "Patchwork," vol. iii. p. 31.

A ground-plan of the Val del Bove and the surrounding parts of the mountain is shown in fig. 63.

ig. 63.—Plan of the Val del Bove, Moun

148. The sudden sinking of the ground by which these crater-formed cavities are produced, is often attended with the sudden production of lakes, filling such cavities with water from subterranean sources. Such lakes are sometimes supplied with water at a high temperature, as was the case in one produced in 1835 in Cappadocia, near the ancient Cæsarea, and in 1820 in the island of St. Michael, one of the Azores.

149. Volcanic islands generally are found to affect the semilunar form, of which Santorin, fig. 58, is an example. Thus the island of Sabrina, already mentioned, which appeared in 1811 among the Azores, at the moment of its rise above the waters presented a crater which opened towards the south and was terminated by crevasses, or openings, from which issued a current of boiling water, figs. 64 and 65.

The island of Julia, which appeared to the south-west of Sicily in 1831, assumed a similar form, and on the 6th of September, 1835, Captain Thayer, the French navigator, found to the north of New Zealand a similar rock recently formed near the surface of the water, which included a lagoon, having a single issue, and within which the water was boiling.

150. These craters of elevation have sometimes continued permanently in the form which they first assumed, but they have also frequently been subject to subsequent changes of form from age to age. The case of Vesuvius, which underwent a remarkable change in 79 A.D., has been already mentioned. The Peak of Teneriffe rises within a circular enclosure, the sides of which are vertical, and rise to a height of from twelve hundred to two

thousand feet. The volcano of Taal, in the island of Lucon, one of the Philippines, is placed in the centre of a basin filled with

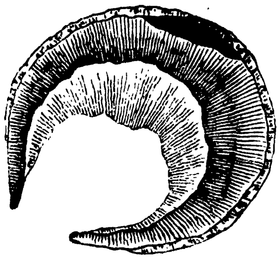
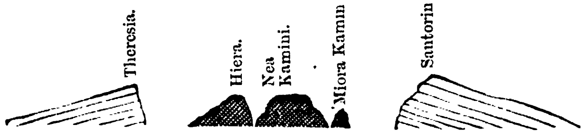


Fig. 64. Forms of volcanic islands. Fig. 65.

water and surrounded by steep and elevated rocks, which leave a single issue from it as in the cases already described.

151. A similar example of this form is presented in the case of Barren Island in the Bay of Bengal (fig. 66, p. 65), which consists of a circle of high mountains, into which the sea flows through a single opening, and of which the centre is occupied by a volcano two thousand feet high, which was in full activity at the time of the discovery of the island.

152. The islands of Santorin and Theresia, already described, form probably the borders of vast craters of elevation. Ancient historians cite them as having appeared long before the Christian era, after a succession of violent earthquake shocks, and in accordance with this tradition, they present strata inclined outwards, as shown in fig. 67; the islands more recently elevated



having issued from the middle of the crater. The strata observed in Santorin and Theresia, are inclined from the centre in accordance with the principle explained in (140).

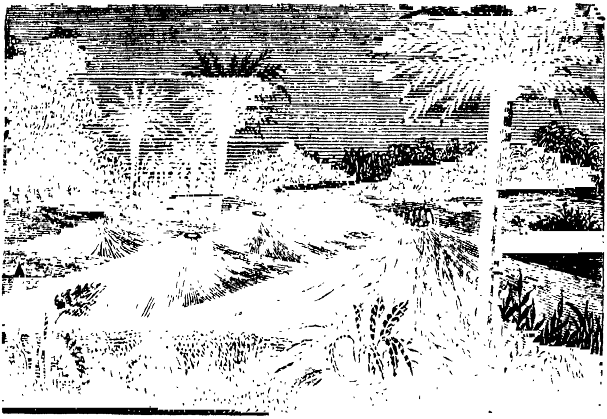


Fig. 72.—THE SALSES, OR MUD VOLCANOES, OF CARTHAGENA.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

CHAPTER VI.

153. It has been impossible to obtain direct observations of the interior of craters when in a state of active eruption, but when they have been approached immediately after the cessation of an

eruption, these cavities appear to have generally a conical form, the base of the cone being presented upwards, and the lower part filled with consolidated lava, by which the principal chimney of the crater is covered. Sulphurous vapour is observed to issue from its fissures and interstices, sometimes several open gulfs are seen, from some of which vapours are emitted, and at the bottom of others incandescent lava is seen. Others again are silent and dark, and inspire an indescribable sense of terror.

154. The crater Stromboli, which has been in activity since the most ancient times, presents at present the same appearances as those which were described by Spallanzani, in 1788. It is constantly filled with lava in a state of fusion, which alternately rises and falls in the cavity. Having ascended to ten or twelve yards below the summit of the walls, this boiling fluid is covered

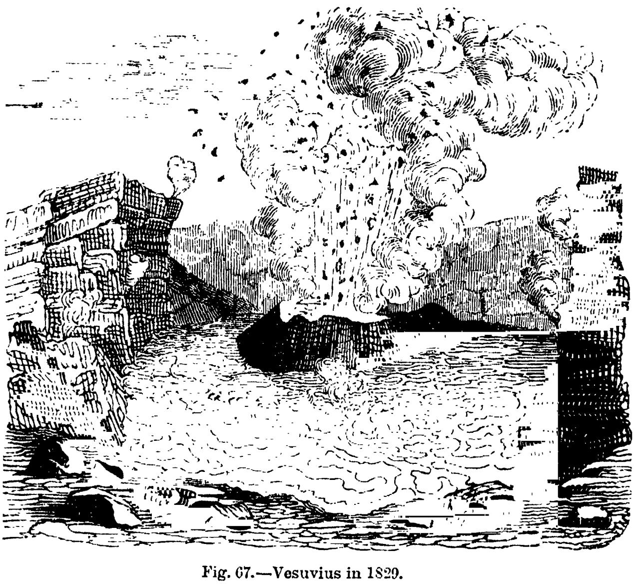


Fig. 67.—Vesuvius in 1829.

with large bubbles, which burst with noise, letting enormous quantities of gas escape from them, and projecting on all sides scoriaceous matter. After these explosions, it again subsides, but only to rise again and produce like effects—these alternations being repeated regularly at intervals of some minutes. In craters

where the lava is less fluid than in that of Stromboli, new cones are sometimes formed in the midst of the crater, which first rise in the form of a dome, and then burst out so as to form a small active volcano in the middle of the crater of the great one. This phenomenon is often presented within the crater of Vesuvius (fig. 67) and was more particularly witnessed in 1829.

155. Sometimes the lava, which is pressed upwards instead of being violently ejected, spreads itself in a sheet of greater or less thickness over the surface (fig. 68) where it hardens, and is subsequently covered by other deposits. Cases have been found also where a succession of these strata, formed at different intervals, with interposed strata of other matter, have been observed (fig. 69). In such cases the matter forming the superior stratum is seen to

Fig. 68.

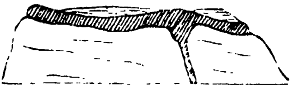
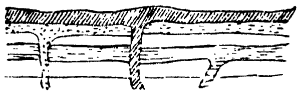


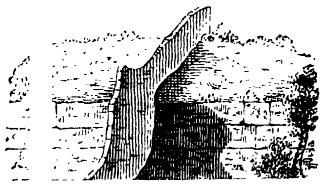
Fig. 69.



have passed in a liquid state through the inferior strata previously described.

156. It often happens that the lava is solidified in clefts, which are nearly vertical, and thus forms walls, called *dykes*, which frequently rise to the surface. In such cases the solidified lava, being much harder and less susceptible of degradation from atmospheric and aqueous influences, remains standing when the matter surrounding it is swept away, and thus forms a wall rising above the general surface (fig. 70).

Fig. 70.



157. The phenomena of Salses, or mud volcanoes, has been already briefly noticed in our Tract upon "Earthquakes and Volcanoes," Vol. IV. p. 169. The mud volcanoes are characterised also by the conical form, but their cones are much less elevated, their slopes being flatter (fig. 72). They have at their summit a crater-formed cavity frequently filled with liquid mud, on which large bubbles are continually formed which, bursting, scatter around them earthy matter. There are sometimes, over a surface of little extent, a great number of these cones in full activity, some of which have a height of ten or twelve yards. Sometimes such an assemblage of cones is found at the summit of a mound from fifty to two hundred yards in height, formed of argillaceous

matter, which appears to have been the result of former ejections. The middle is often formed of a lake of mud, the surface of which is more or less consolidated. In certain countries these mounds are found permanently dried, all disengagement of gas, water, and earth having altogether ceased, but it sometimes happens that the same phenomena after long cessation are renewed with violence.

158. Fumarolles and Geysers are the names given to eruptions of steam or boiling water issuing from crevices in volcanic districts, remarkable examples of which are presented in the country surrounding the celebrated volcano of Hecla, in Iceland. Eruptions of hot steam are projected from the crevices of the soil in the form of white columns, rising to heights of from 30 to 60 feet, and often with noise similar to that with which high pressure steam issues from the safety-valve of a boiler. Such phenomena are manifested on a considerable scale in Tuscany, in the neighbourhood of Monte Cerboli, Castel Nuovo, and Monte Rotondo, and are generally disposed in a single line of from 20 to 25 miles in length.

These jets of vapour in all cases include chemical agents, which attack the rocks with which they come in contact; thus the vapour ejected from Vesuvius includes hydrochloric acid, that of the Solfatara, of Pozzuoli, includes sulphurous acid, and that of Tuscany, boric acid.

159. The Geysers are volcanic eruptions of boiling water, some continued, others intermitting, which prevail in immense numbers in Iceland. One of these hot springs is mentioned which, from half-hour to half-hour, projects a column of boiling water 18 feet in diameter to a height of 150 feet (fig. 71).

The water thus ejected contains a certain proportion of silica, which is deposited in a state of hydrate upon all the surrounding bodies, and forms sometimes mounds of considerable extent, at the summit of which is an opening, from which the liquid issues.

Besides silica, the water of the geysers also contains, in a small proportion, the carbonates or sulphates of soda, ammonia, potash, and magnesia, besides a minute proportion of carbonic acid.

160. Calcareous as well as volcanic countries present vast depressions of the ground analogous to craters, but instead of being nearly circular like those of volcanoes, they are most frequently oblong and very irregular. Such cavities are frequent in the mountains of the Jura. These are generally oblong hollows, like clefts, which sometimes extend to a great distance, forming oblong mounds parallel to each other, with salient summits. These depressions or cavities (fig. 73) have received the name of

valleys of elevation, though they differ in nothing except their form from craters of elevation.

Fig. 73.

161. Elevations of the superficial crust often take place in a series of parallel lines forming so many parallel ridges with intermediate hollows, as if an upheaving force had been exerted by the subjacent strata in a series of parallel directions vertically under the ridges thus produced. The Jura mountains present great numbers of examples of this (fig. 74).

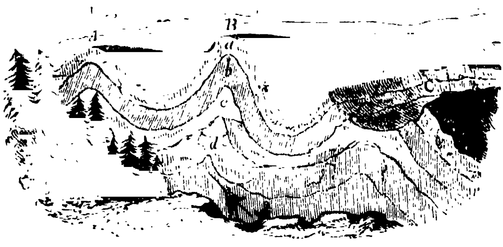


Fig. 74.—Section of ridges in the Jura Mountains.

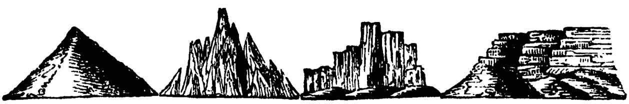
162. The changes in the condition of the earth's surface attending the undulations and disruptions of its crust, which have been noticed above, excite attention because of the sudden catastrophes which often attend them, and the wide devastation which they sometimes spread. There are, however, other agencies exterior to the surface, of which the accumulated effects, produced in long intervals of time, are not less important. The principal of these are air, water, and heat, acting separately or together, upon the solid matter of the external surface of the terrestrial crust. These operate mechanically by fracture and abrasion, physically by dissolution and disintegration, and chemically by decomposition.

The waters of the ocean evaporated by heat rise into the superior parts of the atmosphere, and are carried by atmospheric currents in their course towards the most elevated parts of the land, where they are condensed, and upon which they are precipitated in the liquid state; thence they descend along the declivities, forming rivers and lakes, and sometimes penetrating the crust so as to form springs, until at length, sweeping over the land, they return to the deep, carrying with them, however, a large quantity of detritus of the solid crust, over which they have passed, and which they deposit in the bottom of the sea to form new systems of strata.

Independently of water, air itself by its mechanical action upon solid matter detaches, fractures and abrades more or less of it. The water suspended in the form of vapour in the atmosphere penetrates the pores and interstices of rocks to a greater or lesser extent, according to their density and structure. In times of drought it is again expelled by evaporation, and being thus alternately and incessantly absorbed and dismissed, it at length disintegrates the superficial strata of the rocks, to whatever depth it may penetrate.

Such effects are observable in all cases where extensive sections of the solid crust are made, whether by natural or artificial causes. They are thus seen upon the face of the cliffs which overhang the sea, in the escarpments of ravines which pass through mountain-chains, and in the sides of the vast cuttings artificially produced in quarrying, and still more in the construction of roads, railways, and canals. These effects are, of course, the more prompt and sensible, as the matter composing the rocks is more susceptible of imbibing humidity and of being deprived of it by evaporation. All mountains exhibit traces of such effects in some forms, determined by the various degrees in which their strata are susceptible of them. Thus, while some, like volcanic cones, assume uniform slopes in a conical form, fig. 75 A; others, those composed of gneiss, for example, assume the forms of pointed and dentated peaks, fig. 75 B. Numerous examples of

Fig. 75.



A B C D

these are seen in the chains of the Alps, where they take the names of *needles*, *teeth*, and *horns*, (aiguilles, dents, and cornes,)

according to their varying forms. Calcareous cliffs assume cylindrical forms, fig. 75 C, which seem at a distance to resemble fortifications. The faces of these cliffs are often worn into a succession of terraces or steps, as in fig. 75 D.

163. The effects of long-continued atmospheric action upon the forms of solid rocks, are seen in many places on the surface of continents, which the sea has not approached within historic times. Certain granites are thus disintegrated so profoundly, as to reduce the under-surface of the strata to a mass of gravel, forming holes into which the pluvial water from ravines flows in all directions. These rocks are also sometimes met with worn into rounded forms, and piled one upon another, so as to be supported only at a single point, forming what are popularly called *rocking-stones*, fig. 76 B. Cases of this kind are especially presented in the case of certain porphyritic granites. In mountains where granite is decomposed with facility, it has been remarked that masses of these rocks, more or less divided, present a sort of horizontal layers, separated by vertical fissures, so as to reduce the whole to a pile of irregular parallelopipeds, fig. 76, C. The angles and edges being often worn away, the mass is reduced to a form resembling a pile of cheeses, fig. 76 A.

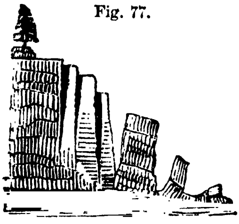
164. Solid rocks are often traversed by vertical crevices filled with matter more easily penetrable by water. In such cases, the pluvial waters entering these crevices dissolve and ultimately sweep away the matter which fills them, leaving the parts thus separated without support. These ultimately fall to the foot of the cliff (fig. 77).

165. When waters bathe the foot of steep cliffs, they have a tendency to dissolve and decompose their lower strata, leaving

the superior ones undisturbed and, consequently, overhanging. When this action is continued to a certain point, the cliffs thus overhanging fall by their weight (fig. 78).

It sometimes happens that the accumulation of the débris of such cliffs which takes place below them, operates as a barrier to the waves, and so, for a time, protects them from further degradation (fig. 79). In some cases the natural form of the rocks exposed to the action of the waves enables them to resist these effects, and such forms are accordingly often imitated in the construction of harbours and breakwaters (fig. 80).

Fig. 77.



166. Cascades have often the same effect in the degradation of the cliffs over which they fall, as have the action of waves directed against their base. When such cliffs are formed of

Fig. 78.

alternate calcareous and argillaceous matter, the former, being more susceptible of disintegration than the latter, absorbs and is

Fig. 79.

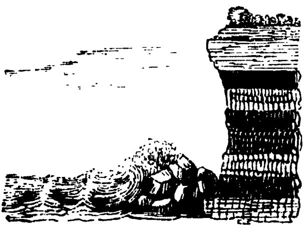


Fig. 80.

worn away by the water either in its fall, or by its recoil from the foot of the cascade; the cliff, therefore, over which the torrent falls soon overhangs (fig. 81) and at length is broken off by its weight.

167. It is to the operation of such causes, as well as to the action of icebergs floating from the Pole, that various forms of rocks found in the ocean, but more especially in the neighbourhood of continents, must be ascribed. The action of the sea disintegrates the softer parts, leaving the harder standing, and thus forms the most capricious arc produced. Wide clefts and openings are made between solid rocks through which the sea passes, and in some cases the rocks are broken into rude and irregular columns and needles (figs. 82 and 83.)

Fig. 81.

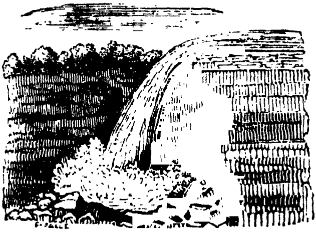
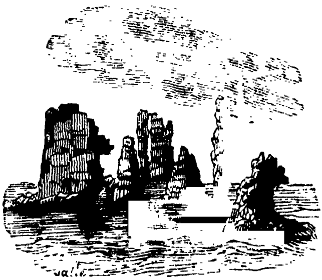


Fig. 82.

Fig. 83.



Other similar examples are presented in the case of the chalk-cliffs near the French village of Etretat on the Channel coast (fig. 84) and also in the porphyritic and granitic columnar rocks of the Shetland Isles (fig. 85).

168. Thus, in fine, it appears that there are, and constantly have been, within historic times, natural agencies in operation upon the surface of the globe, sufficient to explain all those phenomena observed by modern geologists, which, when first brought under notice, excited sentiments of such unmixed wonder. Alternate elevations and depressions of the earth's crust, either sudden or gradual, are recorded in all times; and it is easy to imagine that, in proportion as the shell of solid matter which incloses the igneous central fluid was less and less thick, and

consequently less and less resisting, so at more and more remote periods, these undulations, and their consequent disruptions and explosions, must have been much more frequent, and attended by catastrophes infinitely more violent. The volcanic eruptions which have taken place within historic times, may be regarded as miniature reproductions of the phenomena of which the globe was the theatre at much more remote geological dates. The wear, abrasion, decomposition, and transport of the solid materials of the earth's crust by the action of atmosphere and the waters of the ocean, when continued through periods compared with which that limited by the existence of the human race is but a unit, can easily be imagined to have produced all the effects which are visible on the earth's surface, and to greater or less depths within its crust. The deposits formed by the detritus of the land

Fig. 84.

Fig. 85.

carried by the currents of rivers to their embouchures, exhibit on a small scale the stratification produced by pre-Adamite seas. In a word, all the geological phenomena discoverable by the sections, natural or artificial, of the earth's crust, admit of clear and satisfactory explanation, by merely imputing to the physical agents now in operation an energy proportional to the diminished thickness of the earth's crust, and effects due to a continuance of action for periods of time, compared with which the common chronological units must be regarded as insignificantly minute.

Having thus briefly indicated the natural causes to which geological phenomena must be ascribed, we shall resume the subject which we had dropped, and continue our notice of some of these results, which illustrate the past condition of the earth.

169. There exists in England, in the Isle of Portland, as well as elsewhere, and on various parts of the continent, a stratum called by miners and quarrymen the "*dirt-bed.*" This consists of

a layer about one foot in thickness, composed of dark brown friable loam, containing a large proportion of earthy lignite, and, like the recent soil of the island, many water-worn stones and pebbles. It seems to have been a bed of vegetable mould, which at a remote geological epoch supported an abundant and luxuriant vegetation, for we find in it and upon it innumerable trunks and branches of cone-bearing trees and cycadeous * plants. Above this bed are found layers of finely-laminated cream-coloured limestones, the total thickness of which is about ten feet, and upon which is deposited the modern vegetable soil; but this latter at present, instead of supporting cycadeous plants and pine forests, barely maintains a scanty vegetation.

The most remarkable circumstance attending this dirt-bed, as it is called, is the position of the trees and plants found on it. They are still erect, as though they had been suddenly petrified while growing in their native forests, with their roots in the vegetable soil and their trunks extending into the limestone above it.

Immediately below it is a thick stratum of fresh-water limestone, of little value for building; and below this again is the stratum of the celebrated Portland stone so extensively used for that purpose. The consequence is that the dirt-bed and its interesting materials, little regarded by quarrymen, are cast away and scattered about as mere rubbish, in order to get at the layer of building-stone which lies below them. "On one of my visits to the island (in the summer of 1832)," says Dr. Mantell, "the surface of a large area of the dirt-bed was cleared, preparatory to its removal, and the appearance presented was most striking. The floor of the quarry was literally strewn with fossil wood, and before me was a petrified forest, the trees and plants, like the inhabitants of the city in Arabian story, being converted into stone, yet remaining in the places which they occupied when alive! Some of the trunks were surrounded by a conical mound of calcareous earth, which had evidently, when in a state of mud, accumulated round the stems and roots. The upright trunks were generally a few feet apart, and but three or four feet high; their summits were broken and splintered, as if they had been snapped or wrenched off by a hurricane, at a short distance from the ground. Some were two feet in diameter, and the united fragments of one of the prostrate trunks indicated a total length of from thirty to forty feet; in many specimens portions of the branches remained attached to the stems. In the dirt-bed, there were numerous trunks lying prostrate, and fragments of branches.

"The external surface of all the trees I examined was weather-

* Such as palms and ferns.

worn, and resembled that of posts and timbers of groins or piers within reach of the tides, and subjected to the alternate influence of the water and atmosphere; there are but seldom any vestiges of the bark.

"The fossil plants related to the recent Cycas and Zamia,* occur in the intervals between the pine-trees; and the dirt-bed is so little consolidated, that I dug up with a spade, as from a parterre, several specimens that were standing on the very spot where they originally grew, having, like the columns of the temple of Pozzuoli, preserved their original erect position amidst all the revolutions which have subsequently swept over the surface of the earth, and buried them beneath the accumulated detritus of innumerable ages. These fossil plants, though related to the recent Cycadeæ, belong to a distinct genus.† There are two species—one is short, and of a spheroidal form (M. nidiformis); the other is longer, and subcylindrical (M. cylindrica). ‡

"The trees and plants are completely silicified, and their internal structure is beautifully preserved in many examples; the wood, microscopically examined, displays the organisation of the Araucaria. A cone has been found in the dirt-bed, which Dr. Brown considers to be nearly related to the fruit of the Norfolk Island pine (Araucaria excelsa). The Portland and Isle of Wight fossil trees appear to belong to the same species of Coniferæ." §

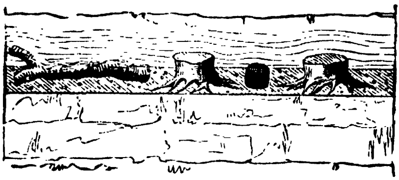


Fig. 86.—Section of the Portland dirt-bed.

170. The presence of plants analogous to the modern Cycas and Zamia shows that the climate of England, at the time when the vegetation of this stratum flourished, must have been

* These plants are so common in conservatories that their general appearance must be familiar to the reader. In the Botanic Gardens at Kew there are magnificent specimens of Cycas and Zamia, and of other plants of hot climates, of which related forms occur in the Wealden.

† Named by M. Adolphe Brongniart, *Mantellia.*

‡ Specimens of the former species are called "*crows'-nests*" by the quarrymen, who believe them to be birds' nests originally built by crows in the pine-trees, and which have since become petrified.

§ Mantell, p. 387.

analogous to that of the tropics, a fact which is in conformity with what has already been explained.

171. The coal deposits are everywhere attended with similar results. Entire trees are found, some of which are standing upright with their roots penetrating the stratum below them, exactly as they penetrated the soil on which they grew. Several examples of these have been presented in England, one of the most remarkable of which occurred in the construction of the railway between Manchester and Bolton. Near Dixonfold five large stems of Sigillariæ were found erect with their roots striking into layers of clay below. They stood upon the same level one beside the other, the trunks being surrounded and filled by soft blue shale, and the carbonised bark being all that remained of the original structure. All these trunks seemed to have been broken violently off at a point four or five feet above the roots, no traces of the upper parts of the trees being discovered.

172. On the coast of Northumberland, within a space of half a

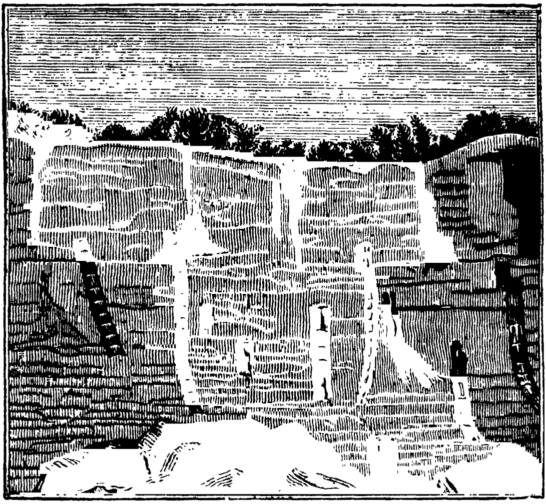


Fig. 87.—Section of the Treuille Mine at St. Etienne.

mile in length, twenty upright trees were discovered by Mr. Trevelyan, and similar ones were found in the same coal-field at some distance, as if they had been the continuation of a submerged forest like that of the Isle of Portland.

In the Newcastle coal-field a stratum of sandstone occurs

nearly five hundred feet below the surface, on which numerous trees have been found standing erect from two to eight feet in circumference, with their roots struck into thin layers of coal.

173. "In a colliery near Wolverhampton," says Hugh Miller, "the bottom coal rises to view, and where the surface has been cleared of the alluvial covering, it presents the appearance of a moor on which a full-grown fir-wood had been cut down a few months before, and only left the stumps behind. Stump rises beside stump, to the number of seventy-three in all: the thickly clinging roots strike out on every side into what seems once to have been vegetable mould, but now exists as an indurated brownish-coloured shale. Many trunks, sorely flattened, lie recumbent on the coal; several are full thirty feet in length, while some of the larger stumps measure rather more than two feet in diameter. There lie, thick around, Stigmariæ, Lepidodendra, Calamites, and fragments of Ulodendra; and yet with all the assistance which these lent, the seam of coal formed by this ancient forest does not exceed five inches in thickness. Not a few of the stumps in this area are evidently water-worn. The prostrate forest had been submerged, and molluscs lived, and fishes swam over it. This upper forest is underlaid by a second, and even a third: we find three full-grown forests closely packed up in a depth of not more than twelve feet." *

174. M. Alexandre Brongniart † describes a coal-pit at Treuille near St. Etienne, in the neighbourhood of Lyons, which contains enormous stems of Calamites and other trees in erect positions (fig. 87). These and similar effects are considered as proofs that the coal was produced by the submergence of a forest which grew upon the spot. This particular mine is very favourable for observations being in the open air, and presenting a natural succession of the strata of clay, slate, and coal, with four layers of compact iron-ore in flattened nodules, accompanied and even penetrated by vegetable remains.

The upper ten feet of the quarry consist of micaceous sandstone, which is in some instances stratified, and in others has a slaty structure. In this bed are enormous vertical stems traversing all the strata, and appearing like a forest of plants resembling the bamboo or large *Equiseta* petrified on the spot on which they grew. The stems are of two kinds, one long and thin, from one to four inches in diameter, and nine or ten feet high,

* First Impressions of England and its People, by Hugh Miller, p. 223.

† Notice sur les Vegetaux fossils traversants les Couches du Terrain houilleux, par M. A. Brongniart, Paris, 1821.

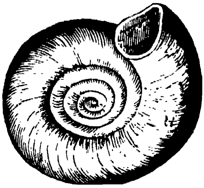
consisting of jointed and striated cylinders with a thin coaly bark. The other and less common species consist of hollow cylindrical stems spreading out from the base like a root.

Fig. 88.

Fig. 89.

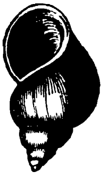
Limnea longiscata.

Fig. 90.



Planorbis evonphalus.

Fig. 91.



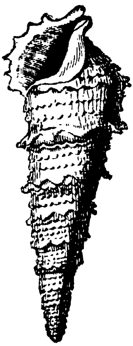
Paludina lenta.

Fig. 92.

Melania.

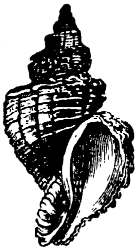
175. The character of the waters, according as they may have been fluviatile and lacustrine or marine, from which the several strata forming the crust of the earth were deposited, is betrayed

Fig. 93.



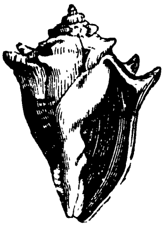
Cerithium mutabile.

Fig. 94.



Murex alveolatus.

Fig. 95.



Voluta athleta.

Fig. 96.

Venericardia imbricata.

by the nature of the organic remains which these strata severally contain. Thus, if we find shells (figs. 88 to 92) analogous in their character to existing fresh-water shells, it may be inferred that the deposits were fluviatile and lacustrine, or at all events that they were fresh-water deposits.

If, on the other hand, none but marine shells (figs. 93 to 96) be found in any stratum, it may be inferred that such stratum was submerged by the ocean from which the deposits were made.

In cases where the organic remains are of a mixed character, containing shells and other fossils, some analogous to existing marine and other species, it may be inferred that such deposits were made at the embouchures of rivers.

By such inductions it has been ascertained that extensive tracts of the surface of the globe, which are now dry land and raised to elevations considerably above the level of the sea, must, at various former epochs, have been submerged in the waters of the ocean. A great part of France, including the country around Paris, Normandy, Artois, Picardy, Franche-Comté, Burgundy, the Cevennes, Dauphiny, and Provence, present examples of this.

Fig. 108.—Fossil footprints in the strata of the new red sandstone.

THE CRUST OF THE EARTH;

OR, FIRST NOTIONS OF GEOLOGY.

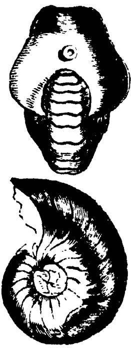
CHAPTER VII.

176. Fossil foraminifera—177. Fossil infusoria—Researches of Ehrenberg. —178. Marine deposits at great heights, produced by former undulations of the land.—179. Organic deposits show that the same parts of the land have undergone a series of alternate elevations and depressions.—180. Example of the Portland beds.—181. Fossil footsteps.—182. Such traces common in the new red sandstone, at Hesseburg, and near Liverpool.—183. Footprints of birds.—184. Fossil rain-drops and ripple-marks.—185. Conclusion.

176. BESIDES the larger class of fossil shells, there are numerous infinitely more minute ones, which have largely contributed to the formation of the actual crust of the globe, the principal of which are the Foraminifera and Infusoria.

The Foraminifera are marine animals of low organisation, and generally of such extreme minuteness, that an ounce of sea-sand will contain three or four millions of them. The body consists of uniform granules enclosed in a skin or membrane

Fig. 97.

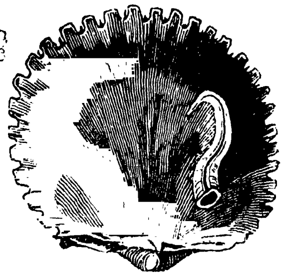


Nautilus truncatus.

Fig. 98.

Ammonites catena.

Fig. 99.



Serpula.

having one or more cavities or digestive sacs. These animals are regarded as *polypes*, and are protected by shells. Some of these shells, such as the Orbiculina, contain a single cell. Others, such as the Nodosaria, consist of several cells disposed in conical or cylindrical directions. Other families have shells, like that of the Nautilus, consisting of a succession of cells in spiral forms.

The Foraminifera derive their name from the structure of the shell, which consists of one or more series of chambers separated from one another by septa or partitions, in each of which there is a small perforation called a foramen.

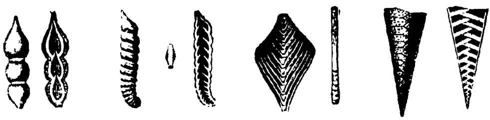
Some specimens of these shells, on a highly magnified scale, are given in figs. 100 to 106.

These microscopic shells, of which from seven to eight hundred fossil species have been discovered, are accumulated in enormous numbers in the strata of the earth, and, in many cases, exclusively form very considerable calcareous deposits, of which the chalk and the cretaceous and tertiary strata present numerous examples in all parts of the world.

177. The Infusoria, the existing species of which are found in

fresh and salt water, are smaller still than the Foraminifera, being only visible by the aid of microscopes of great magnifying power. There are innumerable species of them, which are furnished with siliceous shells, and which, consequently, are accumulated at the bottom of the waters with the contemporaneous microscopic plants. Now, although these beings are so minute that forty thousand millions of them would not fill a space of

Fig. 100. Fig. 101. Fig. 102. Fig. 103.



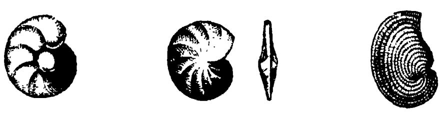
a b a b c a b a b

Fig. 100.—*a.* Nodosaria limbata.
b. Internal arrangement of the cells.
,, 101.—*a.* Marginulina trilobata.
b. The last cell seen from above.
c. The internal arrangement of the cells.

Fig. 102.—*a.* Flabellaria rugosa.
b. Side view, to show the flatness.
,, 103.—*a.* Textularia turris.
b. Internal arrangement of the alternate cells.

more than a cubic inch, M. Ehrenberg has demonstrated that their accumulation in certain parts of the earth's crust has pro-

Fig. 104. Fig. 105. Fig. 106.



a b

Fig. 104.—Rotulina Voltzii.
,, 105.—*a.* Cristellaria rotula.
Fig. 105.—*b.* Edge view, to show the flatness.
,, 106.—Orbiculina numismalis.

duced strata several yards in thickness, and of vast extent; and that in many other cases strata not less extensive are formed by their combination with other conchiferous animalcules. They constitute almost exclusively the polishing slate of Bilin, in Bohemia, which occupies a surface of great extent, probably the site of an ancient lake, and forms a stratum fourteen feet in thickness, composed of the mineralised shields of these animalcules. "The diameter of a single one of these creatures," says M. Ehrenberg, "amounts upon an average, and in the greatest part, to the 3500th of an inch, which equals $\frac{1}{6}$ of the thickness of a human hair, reckoning its average size at the 570th of an inch. The globule of the human blood, considered at the 3600th of an inch, is not much smaller. The blood globules

of a frog are twice as large as one of these animalcules. As the Polirschiefer of Bilin is slaty, but without cavities, these animalcules lie closely compressed. In round numbers, about twenty-four millions would make up a cubic line, and would, in fact, be contained in it. There are 1728 cubic lines in a cubic inch; and therefore a cubic inch would contain, on an average, about forty-one thousand millions of these animals. On weighing a cubic inch of this mass, I found it to be about 220 grains. Of the forty-one thousand millions of animals, a hundred and eighty-seven millions go to a grain; or the siliceous shield of each animalcule weighs about $\frac{1}{187}$ millionth part of a grain."

The remains of these Infusoria are often found in abundance in flints, opals, and more especially in the earthy matter which envelopes the translucent parts. They exist in large quantities, also in most marls, especially in those of lacustrine depositions in calcareous slates of the same formation, and in all chalk strata. They form the chief part of the deposits which fill the gulfs and arms of the ocean, and are found in all the earthy deposits raised from the bottom of the waters in ancient and modern times. They exist in strata sixty feet thick in the low plains of Western Germany, at a depth greater or less under the sands of those countries. It is a remarkable fact, that one of the strata on which the city of Berlin is placed, is formed of the shells of Infusoria which still live and are propagated and sustained, doubtless, by the waters of the Spree, on which that city is built.

M. Ehrenberg has described numerous fossil genera and species of Infusoria found in all parts of the world, and in different strata, a few of which are represented on a high magnified scale in fig. 107.

178. At whatever heights upon the land fresh-water shells and the remains of land animals may be found in the sedimentary strata, no surprise can be excited, since it is perfectly conceivable that at various epochs any portions of the land, whatever be its level, may have been submerged by lakes or overflown by rivers. But we find, also, at all levels, no matter how high, even at the summits of lofty ranges of mountains, marine deposits in strata of immense extent and vast thickness.

179. In many places an analysis of the strata shows the most curious alternations between fresh-water and marine deposits, which can only be explained by the supposition that the crust of the globe at these places has undergone a succession of elevations and depressions, and that after being submerged for an indefinite period, and receiving marine deposits, it was then upheaved so as to become dry land; and that during another indefinite period it was peopled by land and fresh-water animals, and covered with a

certain vegetation: that then it was again submerged, either by fresh water or by the sea, receiving during an indefinite period another stratum, either with fluvial and lacustrine remains or with marine deposits, as the case might be; that subsequently it was again upheaved, and again became the theatre of animal and vegetable life upon dry land, and so on.

180. The Portland dirt-beds, already described, prove the existence there, at remote epochs of the globe, of vegetable soil on a land nearly if not altogether dry, beneath which lay a stratum of marine deposits. It follows, therefore, that before this epoch, and before the deposition of the dirt-bed itself with the remains contained on it, that part of the land must have been submerged by the ocean, and that being upheaved, it afterwards became the theatre of animal and vegetable life, such as we find deposited in

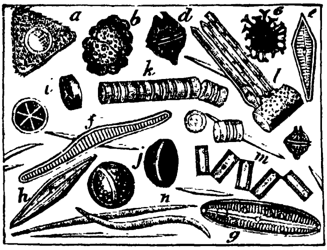


Fig. 107.—Fossil infusoria.

a. Desmidium apiculosum.
b. Euastrum verrucosum.
c. Xanthidium ramosum.
d. Peridinium pyrophorum.
e. Gomphonema lanceolata.
f. Hemanthidium arcus.
g. Pinnularia dactylus.
h. Navicula viridis.
i. Actinocyclus senarius.
j. Pixidula prisca.
k. Gallionella distans.
l. Synedra ulna.
m. Bacillaria vulgaris.
n. Spicula spongiaria.

the dirt-beds. Over the dirt-beds are thick lacustrine deposits of limestone, which lie under the green sandstone, which latter is itself overlaid by the chalk, this latter being evidently a marine formation. Let us see, then, what a curious succession of phenomena is here indicated. The lower marine strata of limestone was first upheaved, and, becoming dry land, was the theatre of rich terrestrial vegetation. It was then submerged by fresh water, and was the place of a lake or deep estuary, in which were formed the strata of limestone, sand, and clay, filled with fluviatile shells, forming a stratum, which from actual observation appears to have a thickness of from seven hundred to a thousand feet. Later still, this was covered by the sea, and marine deposits of green sandstone and chalk were formed upon it, which, at

certain places, had a still greater thickness. In fine, at a later period still, another great elevation of the crust took place, which raised the surface to its present elevation above the waters.

181. Independently of the evidence supplied by organic remains proving that certain strata were at former epochs above the waters and inhabited by land animals, and were subsequently submerged, indications of another order have been supplied by the traces left by animals in the soft surface of the strata, which were afterwards hardened without these traces being effaced. Such traces, therefore, may be regarded as moulds thus accidentally preserved, from which castings might be obtained of those parts of the animals, then living upon the globe, which produced them. Many moulds of shells have been thus found, but the most remarkable indications of this kind consist of the footsteps of certain animals which appear to have been impressed upon the soft surface of the ground, just as the footsteps of any animals might be at present impressed upon the soft sand upon the sea-shore after the retirement of the tide.

182. In 1834 an account was published of remarkable fossil footprints in the new red sandstone at Hesseburg, near Hildburghausen, in Saxony. The largest of these tracks appears to have been made by an animal whose hind-foot was eight inches long, and which, from its resemblance to the human hand, received from Professor Kaup the name of Chirotherium. Some of the tracks, however, appeared to be those of tortoises; and Link suggests that others are those of some colossal species of frog or salamander, fig. 109.

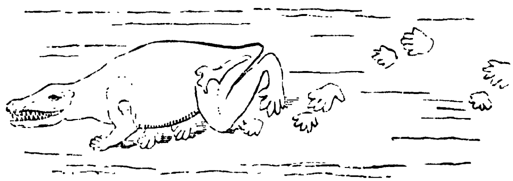


Fig. 109.—Labyrinthodon pachignatus (Owen).

The traces represented in fig. 108 are those found in a sandstone slab at Hesseburg. Various similar tracks have been found in the sandstone quarries at Storeton Hill, near Liverpool. The largest footprint was nine inches long and six inches broad, the length of the step being nearly two feet. Similar tracks were found by Professor Hitchcock in the quarries of Connecticut; and Mr. Scrope found similar marks on a surface bearing ripple-marks in the vast marble-quarries near Bath.

These last are supposed to have been made by some crustaceous animal crawling along the bottom of an estuary; for between the rows of footprints are in some cases observed the impressions of the belly, and in others the trail of the tail.

183. Footprints of birds have been discovered in several quarries in the valley of the Connecticut river, and also in different parts of the state of Massachusetts. Several specimens of these are now in the British Museum. The most remarkable of these is a slab, eight feet by six, exhibiting various tracks of birds, (fig. 110).

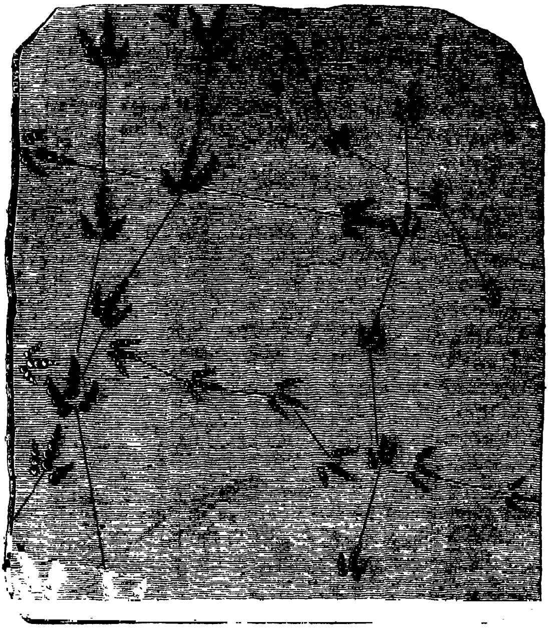


Fig. 110.—Fossil footsteps of birds.

All these marks belong to the birds called *waders*, and appear to have been made upon the sea-shore. Some are small, others of a size so enormous that they could only have belonged to birds twice the size of the largest ostrich. In one case the footprint measures fifteen inches in length by ten in width, without counting the hind-claw, which itself measures two inches. The distance

between the successive footprints varies from four to six feet. The shorter footsteps may be taken as the length of the step when the bird walked at its ordinary pace, and the larger one when it moved more swiftly.

184. A very remarkable concomitant of some of these fossil footprints is the distinct impressions of rain-drops upon the strata. Dr. Dean discovered a stratum containing more than a hundred marks of the feet of birds of various species, the whole surface of which was pitted by the marks produced by a heavy shower of rain. Like marks were observed in Storeton quarry, near Liverpool. The impressions produced by the rain-drops were sometimes perfect hemispheres, an indication of a heavy fall of rain in a vertical direction, and consequently in a calm atmosphere. In other cases the impressions were irregular and oblong, as if the drops had struck the surface obliquely, as when a shower is accompanied by a strong wind.

Professor Hitchcock also mentions specimens of sandstone obtained from various parts of the United States, showing at once footprints, ripple-marks, and rain-drops, the latter being elongated by the direction of the wind when the shower was falling.

These phenomena can only be explained by the fact that the marks were made upon the moist sand formed on the shores of an estuary or tidal river, between high and low water mark, which then was allowed to dry and harden by the action of the sun and air between two successive tides. The waters on the return of the tide would wash up silt to cover up the impressions without impairing their accuracy; the two layers uniting so as to exhibit when separated the one a shield, and the other a cast from it of the form thus impressed.

185. Our necessary limits, rather than the exhaustion of the subject, compel us here to close these first glimpses of geology. We propose, however, in a succeeding paper, to resume the subject, and to give a brief sketch of the History of the Earth from the first formation of its solid crust to the last great act of creation which called the human race and its concomitant tribes into existence.

CUVIER

Fig. 1.—Cuvier.

CUVIER

Fig. 2.—Cuvier.

THE STEREOSCOPE.

1. Surprising effect of the instrument explained.—2. Causes of visual perspective and relief.—3. Effects of binocular parallax.—4. Example of the bust of Cuvier.—5. Principle of the stereoscope.—6. Origin of the name.—7. Wheatstone's reflecting stereoscope.—8. Sir David Brewster's lenticular stereoscope.—9. Method of obtaining stereoscopic pictures.—10. How the effects of relief are produced.—11. Natural relief greatly exaggerated.

1. The surprise excited by the impressions of perspective and relief produced by the stereoscope have never, as we think, been fully or adequately explained. This emotion of astonishment does not merely arise, as is commonly supposed, from the fact that such impressions are stronger than those produced by the best executed drawings or paintings, but that, paradoxical as it may seem, they are actually in many cases stronger and more vivid, than any which could be produced by the objects themselves. In a word, the stereoscope has the property of exaggerating the natural effects of perspective and relief. To comprehend this it will only be necessary to revert for a moment to the principles upon which the effects of vision are based.

The mind judges of the relative position, form, and magnitude of visible objects, by comparing their apparent outlines and varieties of light and shade, with previously acquired impressions of the sense of touch. The knowledge that such and such visual appearances and optical effects are produced by certain varieties of form, position, and distance having been already acquired, it substitutes with the quickness of thought the cause for the effect. The continual repetition of such acts, which are necessarily repeated as often as the sense of vision is exercised, and the extreme rapidity with which all such mental operations are performed,

render us unconscious of them, and we imagine that shape, distance, and position are the immediate subjects of visual perception, instead of being consequences deduced from a set of perceptions of a wholly different kind.

2. In drawing and painting, the effects of perspective and relief are therefore reproduced, by transferring to the canvas the same outlines and the same varieties of light and shade, which the objects delineated really present to the eye, and when this has been accomplished with the necessary degree of fidelity and precision, the same impression of distance, perspective, and relief is produced, as that which would be received from the immediate view of the objects themselves which are delineated.

3. In certain exceptional cases, however, a class of visual phenomena is manifested which are quite independent of mere outline and varieties of light and shadow, and which no effort of art can transfer to canvas. Inasmuch, also, as these phenomena, like those already mentioned, are optical effects of distance, form, and position, they become, like the others, indications by which the mind judges of the relative forms and positions of the objects which produce them. Phenomena of this class are manifested, when the objects viewed are placed so near the observer, as to have sensible binocular parallax. The aspects under which they are seen in this case by the two eyes, right and left, are different. Certain parts are visible to each eye which are invisible to the other, and the relative positions in which some parts are seen by one eye, differ from those in which the same parts are seen by the other eye. This difference of aspect and apparent position, arises altogether from the different position of the two eyes in relation to the objects. It is a phenomenon, therefore, which can never be developed, in the case of objects whose distance bears a large proportion to the distance between the eyes, because there is no sensible difference between the aspects under which such objects are viewed by the one eye and the other. The phenomenon, therefore, can only be manifested in relation to objects, whose distance from the observer is a small multiple of the distance between the eyes.

4. To render this more clear, let us imagine a bust presented to an observer at a distance of a few feet, the face being turned obliquely so that one side is presented more to view than the other. Supposing the side which is turned towards the observer to be on his right, it is evident that the nose will intercept, more or less, the view of the side of the face which is on his left, but the part which it thus intercepts will not be the same for both eyes. It will evidently intercept more from the right than the left eye. On the other hand, the right eye will see a part of the

right side of the bust, which will be concealed from the left eye by the projecting parts of the face.

It therefore appears that the two eyes, right and left, will have different views of the bust; so that if the observer were to make an exact drawing of the bust with his left eye closed, and another exact drawing of it with his right eye closed, these drawings would not be identical. One of them would show a part of the bust on the extreme right, which would not be exhibited in the other, and the latter would show a part on the extreme left, which would not be included in the former. Moreover, a part of the cheek and the eye would be shown in the drawing made with the right eye closed, which would not appear in the drawing made with the left eye closed.

Two such views of the same object are shown in figs. 1 and 2, the former being the view presented to the left and the latter to the right eye.

Now it is evident that when such an object is looked at with both eyes open, the two different visual impressions here described are simultaneously perceived, and they become to the mind signs and indications of the actual forms which produce them.

When objects, therefore, can be viewed at distances small enough to be attended with a sensible degree of parallax, their perspective and relief are perceived, not only by the outlines and varieties of light and shade, which are the common indications of perspective and relief at all distances, but also by the class of binocular phenomena which we have just described.

Hence it follows that the perception of relief, and generally of form and relative position in objects whose proximity is sufficient to produce binocular parallax, is much stronger and more vivid than those whose distances, rendering the binocular parallax evanescent, leaves nothing but the outlines and the varieties of light and shadow, by which the mind can form a judgment of form, relative distance, and position.

But since binocular parallax is reduced to the very small amount of half a degree at the distance of 24 feet, it is clear that it can only enter into the conditions by which we perceive perspective and relief, in the case of a very limited class of objects, and is not at all applicable to objects in general whose forms and perspective we habitually contemplate.

5. After what has been explained of the two different views which a near object presents, when looked at successively with the one eye and the other closed, the principle of the stereoscope will be easily understood.

A bust being placed before a competent draughtsman, as above described, at a distance sufficiently small to produce considerable

binocular parallax, let him make two exact drawings of it, one with the right eye closed, and the other with the left eye closed. These two drawings will then represent the object as it is actually seen, when the optic axis of each eye is directed to it. Let us suppose that, by some optical expedient, the two drawings thus made can be so presented to the two eyes, that the optic axis, when directed to them, shall converge at the same angle as when they are directed to the object itself. In that case each eye will obtain the same view which it would obtain if the object itself were placed before it, and the visual perception must necessarily be the same as would be produced by the object looked at with both eyes open.

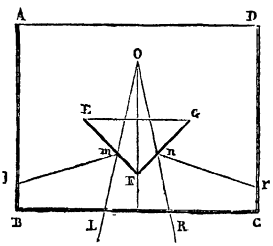
6. Now the optical expedient by which this is accomplished is the *stereoscope*, a name derived from two Greek words, *στερεόν* (stereon), *a solid object*, and *σκοπέω*, (skopeo) *I look at;* inasmuch as the effect is such as to make the observer imagine that a really solid object (in the geometrical sense of the term), instead of a flat surface, is placed before him.

Various optical combinations have been proposed and contrived, for the purpose of producing this effect upon two such drawings as we have here described. In some the visual rays proceeding from the pictures are thrown into the requisite direction by reflection, and in others by refraction.

7. In the first form given to the instrument by Professor Wheatstone, its inventor, the visual rays proceeding from the two pictures were deflected by two plane reflectors placed at a right angle, so that in entering the eyes they proceeded as if they had diverged from a common point, at which the object represented by the pictures would therefore appear to be placed.

Let A B C D (fig. 3) be the ground-plan of a rectangular box, open upon the side A D so as to admit the light. Let R and L be two eye-holes made in the side B C, at a distance apart equal to the distance between the eyes of the observer. Let E F and F G be two plane mirrors placed at right angles to each other. Let a drawing of an object seen with the right eye, the left being closed, be attached to the inside of D C at *r*, and another made from the object seen with the left eye, the right being closed, be in like manner attached at *l* to the inside of A B. Supposing the eyes of the observer to be placed at the holes R and L, the right eye will see by reflection the drawing *r* in the direction R *n*, and the left eye will see the drawing *l* by reflection in the direction L *m*. If the lines L *m* and R *n* be

Fig. 3.

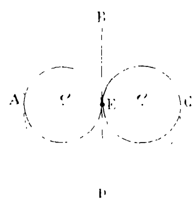


imagined to be continued backwards, they will meet at a certain point O behind the reflectors; and if the drawings r and l be made to correspond with the views which the right and left eyes would have respectively of the object itself, which they represent, placed at O, the impression produced by the two drawings thus seen will be precisely the same as those which would be produced on the right and left eye respectively by the object itself seen at O.

8. In the lenticular stereoscope invented by Sir David Brewster, the form of the instrument to which the public in general in all countries have given the preference, the visual rays proceeding from the two pictures are deflected and made to diverge from the desired distance, by means of two eccentric double convex lenses.

These are formed by cutting a double convex lens A B C D (fig. 4), into two semi-lenses B A D and B C D, in the direction of a plane B D, passing through the centre of the lens. The two eccentric lenses are then cut out of these, so that the diameters A E and C E shall be the semi-diameters of the original lens. It will be evident that a section of the original lens, made by a plane passing through A E C at right angles to its surface, will have the form represented at A E C (fig. 5), and consequently that the two eccentric lenses A E and C E will have their thickest part at E, and their thinnest at A and C. While the geometrical centres of these lenses are at o and o', their optical centres are at the thickest point E of the radius.

Fig. 4.



Now, suppose these two lenses to be set with their edges A and C towards each other in two eye-holes whose distance apart is equal to that of the eyes, and let two objects, P and P′ (fig. 6), be placed before them at a distance equal to their common focal length. According to the properties of lenses already explained, pencils of rays diverging from P and P′, and passing through the lenses, will be, after refraction, parallel respectively to lines drawn from P and P′, through the optical centres E and E′ of the lenses. Thus the visual ray P p will, after refraction, issue in the direction p L, and the ray P′ p' will issue in the direction p' R, so that the points P and P′ will be seen in the directions of L p and R p' converging to the point O.

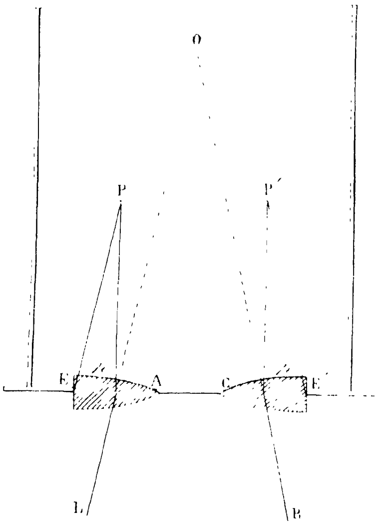
Fig. 5.

Now, if P be a picture of an object as it appears to the left eye, and P′ a picture of it as it appears to the right eye, these two pictures will be brought together at O by the refraction of the lenses, and the eyes will see the combined pictures at O, exactly as they would see the object itself if it were placed there.

An advantage incidental to this arrangement is, that the

convexity of the lenticular eye-pieces A E and C E′, may be such as to produce any desired magnifying effect, within practical limits, upon the two pictures.

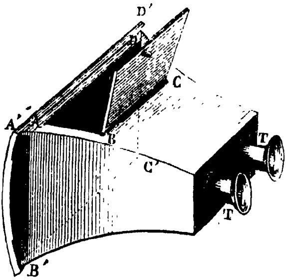
Fig. 6.



The tubes containing the eye-glasses A E and C E′, are made to draw in and out so as to be adapted to different eyes; and they are fixed by pins, which pass into slits made in them in that position in which the deflected rays have the proper degree of divergence.

The form in which this lenticular stereoscope is usually constructed, is shown in fig. 7. The pictures are either opaque or transparent. If they are opaque, they are illuminated through an opening A B C D, covered by a hinged lid, the inside surface of which is coated with tinfoil so as to reflect light upon the pictures. If they are transparent, the base of the instrument A′ B′ C′ D′ has a plate of ground glass set in it, which allows a diffused light to pass through the pictures.

Fig. 7.



9. In what has been stated above, it has been assumed that two drawings of the same object can be produced, differing one from another precisely as the two views of the same object would differ, when viewed by the right and the left eye successively, subject to a given degree of binocular parallax. Now, the difficulty, if

not the total impracticability, of accomplishing this, with the extreme precision which is indispensable, by any process of hand-drawing, will be apparent; and if the stereoscope were dependent on such a process, the most remarkable effects manifested by it would never have been witnessed. Fortunately, however, contemporaneously with this beautiful optical invention, another, still more remarkable, was in progress of improvement. Photography lent its powerful aid to the stereoscope, and supplied an easy and perfectly accurate and efficient means of producing the right and left monocular pictures. If two lines be imagined to be drawn from the object inclined to each other at the angle which measures the proposed binocular parallax, two photographic instruments placed one on each of these lines, at the proper distance from the object, will produce the two desired pictures; or the same instrument would do so, placed successively in the directions of the two lines.

The stereoscopic pictures are accordingly produced by this method either upon daguerreotype plates, photographic paper, or glass. On daguerreotype plates they are necessarily opaque; on glass they are transparent; and on paper may be either opaque or transparent, according to the thickness and quality of the paper.

10. Since the greater number of stereoscopic pictures represent views of objects which must be so distant from the observer as to have no sensible binocular parallax, it may be asked how it is that stereoscopic effects, so remarkable as those which are manifested by such pictures, can be produced. If the stereoscopic effects be the consequences of binocular parallax, and of that alone, how can such effects be produced by pictures of objects, which have no such parallax?

This brings us back to a statement made in the commencement of this notice, that the appearance of perspective and relief produced by the stereoscope is, in most cases, exaggerated, as compared with that produced by an immediate view of the objects themselves, and that it is consequently such as can never be perceived when the objects themselves are looked at; and that hence arises the sensation of surprise that such stereoscopic effects never fail to excite.

If we desire to obtain a pair of stereoscopic pictures of any object of considerable magnitude, a palace or a cathedral, for example, we take a position at such a distance from it as will enable us to obtain, in the camera obscura of the photographic apparatus, a picture of it on a sufficiently small scale. Supposing, then, two lines to be drawn from the centre of the object to the place selected for the camera, making with each other an angle equal to the amount of binocular parallax, which is necessary to produce the stereoscopic effect of perspective and relief; let two

photographic instruments be then placed one on each of these lines, with their optic axes in the directions of the lines respectively, and therefore converging towards the same point of the object, and let the distances of their object glasses from that point be equal. The optical pictures which they will produce will in that case be those which would be seen by two eyes, right and left, having a distance apart equal to the distance between the object glasses of the two photographic instruments.

When the pictures are thus produced on a small scale they are placed in the stereoscope, the eye-glasses of which will have the effect of causing them to be viewed in lines converging at the same angle, as that formed by the optic axes of the two photographic instruments by which the pictures were produced.

11. It will be manifest, then, that the impression produced by the view of such pictures in the stereoscope will be such, as could never be produced by the immediate view of the objects themselves, inasmuch as they could never be seen with any such degree of binocular parallax, as that which has been given to them by the relative position of the two photographic instruments. This parallax will be greater than the natural binocular parallax of the object, in the same proportion as the distance between the centres of the object glasses of the two photographic instruments, is greater than the distance between the eyes. Thus if, in taking such a pair of stereoscopic views of a building, the distance between the photographic instruments is 50 inches, the parallax thus produced will be greater than the natural binocular parallax in the proportion of 50 to 2½, or 20 to 1, and so far as the perception of perspective and relief depends on binocular parallax, that which is produced from viewing the pictures of the building in the stereoscope, will be 20 times more strong and vivid than that which is produced by the view of the building itself, seen from the station at which the pictures are taken.

It is then rigorously true, that the surprise and admiration excited by the stereoscope, does not arise from the truth of the picture which it presents, but from the strong exaggeration of perspective and relief which it exhibits. It is very true that no art of the draughtsman or painter could produce any such effects; but it is equally true that no such effects could be produced by the objects themselves.

Among the most interesting and instructive as well as surprising effects of the stereoscope, are those which it exhibits when stereoscopic views of geometrical solid figures are exhibited in it. The variety of these is endless. But since no mere verbal description could convey any adequate idea of them, we can only invite the reader's attention to this class of objects.

Fig. 5.

COMETS.

CHAPTER I.

I. Cometary Orbits: 1. Prescience of the astronomer.—2. Strikingly illustrated by cometary discovery.—3. Motion of comets explained by gravitation.—4. Conditions imposed on the orbits of bodies which are subject to the attraction of gravitation.—5. Elliptic orbit.—6. Parabolic orbits.—7. Hyperbolic orbits.—8. Planets observe in their motions order not exacted by the law of gravitation.—9. Comets observe no such order in their motions.—10. They move in conic sections, with the sun for the focus.—11. Difficulty of ascertaining in what species of conic section a comet moves.—12. Hyperbolic and parabolic comets not periodic.—13. Elliptic comets periodic like the planets.—14. Difficulties attending the analysis of cometary motions. —15. Periodicity alone proves the elliptic character.—16. Periodicity

combined with the identity of the paths while visible establishes identity.—17. Many comets recorded—few observed.—18. Classification of the cometary orbits.—II. ELLIPTIC COMETS REVOLVING WITHIN THE ORBIT OF SATURN: 19. Encke's comet.—20. Table of the elements of the orbit.—21. Indications of the effects of a resisting medium.—22. The luminiferous ether would produce such an effect.—23. Comets would ultimately fall into the sun.

I.—COMETARY ORBITS.

1. FOR the civil and political historian the past alone has existence—the present he rarely apprehends; the future never. To the historian of science it is permitted, however, to penetrate the depths of past and future with equal clearness and certainty: facts to come are to him as present, and not unfrequently more assured than facts which are passed. Although this clear perception of causes and consequences characterises the whole domain of physical science, and clothes the natural philosopher with powers denied to the political and moral inquirer, yet foreknowledge is eminently the privilege of the astronomer. Nature has raised the curtain of futurity, and displayed before him the succession of her decrees, so far as they affect the physical universe, for countless ages to come; and the revelations of which she has made him the instrument, are supported and verified by a never-ceasing train of predictions fulfilled. He "shows us the things which will be hereafter," not obscurely shadowed out in figures and in parables, as must necessarily be the case with other revelations, but attended with the most minute precision of time, place, and circumstance. He converts the hours as they roll into an ever-present miracle, in attestation of those laws which his Creator through him has unfolded; the sun cannot rise—the moon cannot wane—a star cannot twinkle in the firmament, without bearing witness to the truth of his prophetic records. It has pleased the "Lord and Governor" of the world, in his inscrutable wisdom, to baffle our inquiries into the nature and proximate cause of that wonderful faculty of intellect—that image of his own essence which he has conferred upon us; nay, the springs and wheelwork of animal and vegetable vitality are concealed from our view by an impenetrable veil, and the pride of philosophy is humbled by the spectacle of the physiologist bending in fruitless ardour over the dissection of the human brain, and peering in equally unproductive inquiry over the gambols of an animalcule. But how nobly is the darkness which envelopes metaphysical inquiries compensated by the flood of light which is shed upon the physical creation! *There* all is harmony, and order, and majesty, and beauty. From the chaos of social and political phenomena exhibited in human records—phenomena

unconnected to our imperfect vision by any discoverable law, a war of passions and prejudices, governed by no apparent purpose, tending to no apparent end, and setting all intelligible order at defiance—how soothing and yet how elevating it is to turn to the splendid spectacle which offers itself to the habitual contemplation of the astronomer! How favourable to the development of all the best and highest feelings of the soul are such objects! the only passion they inspire being the love of truth, and the chiefest pleasure of their votaries arising from excursions through the imposing scenery of the universe—scenery on a scale of grandeur and magnificence, compared with which whatever we are accustomed to call sublimity on our planet dwindles into ridiculous insignificancy. Most justly has it been said, that nature has implanted in our bosoms a craving after the discovery of truth, and assuredly that glorious instinct is never more irresistibly awakened than when our notice is directed to what is going on in the heavens. "Quoniam eadem Natura cupiditatem ingenuit hominibus veri inveniendi, quod facillime apparet, cum vacui curis, etiam quid in cœlo fiat, scire avemus; his initiis inducti omnia vera diligimus; id est, fidelia, simplicia, constantia; tum vana, falsa, fallentia odimus." *

2. Such reflections are awakened by every branch of astronomy, but by none so strongly as by the history of cometary discovery. No where can be found so marvellous a series of phenomena foretold. The interval between the prediction and its fulfilment has sometimes exceeded the limits of human life, and one generation has bequeathed its predictions to another, which has been filled with astonishment and admiration at witnessing their literal accomplishment.

3. In the vast framework of the theory of gravitation constructed by Newton, places were provided for the arrangement and exposition not only of all the astronomical phenomena which the observation of all preceding generations had supplied, but also for a far greater mass which the more fertile and active research of the generations which succeeded him have furnished. By this theory all the known planetary motions were explained, and planets previously unseen were felt by their effects, their places ascertained, and the telescope of the observer guided to them.

But transcendently the greatest triumph of this celebrated theory was the exposition it supplied of the physical laws which govern the motions of comets as distinguished from those which prevail among the planets.

4. It is proved in the propositions demonstrated in the first

* Cic. de Fin. Bon. et Mal., ii. 14.

book of Newton's Principia, which propositions form in substance the ground-work of the entire theory of gravitation, that a body which is under the influence of a central force, the intensity of which decreases as the square of the distance increases, must move in one or other of the curves known to geometers as the "CONIC SECTIONS," being those which are formed by the intersection of the surface of a cone by a plane, and that the centre of attraction must be in the FOCUS of the curve; and in order to prove that such curves are compatible with no other law of attraction, it is further demonstrated that whenever a body is observed to move round a centre of attraction in any one of these curves, that centre being its focus, the law of the attraction will be that of gravitation; that is to say, its intensity will vary in the inverse proportion of the square of the distance of the moving body from the centre of force.

Subject to these limitations, however, a body may move round the sun in any orbit, at any distance, in any plane, and in any direction whatever. It may describe an ellipse of any eccentricity, from a perfect circle to the most elongated oval. This ellipse may be in any plane, from that of the ecliptic to one at right angles to it, and the body may move in such ellipses either in the same direction as the earth or in the contrary direction. Or the body thus subject to solar attraction may move in a parabola with its point of perihelion at any distance whatever from the sun, either grazing its very surface or sweeping beyond the orbit of Neptune, or, in fine, it may sweep round the sun in an hyperbola, entering and leaving the system in two divergent directions.

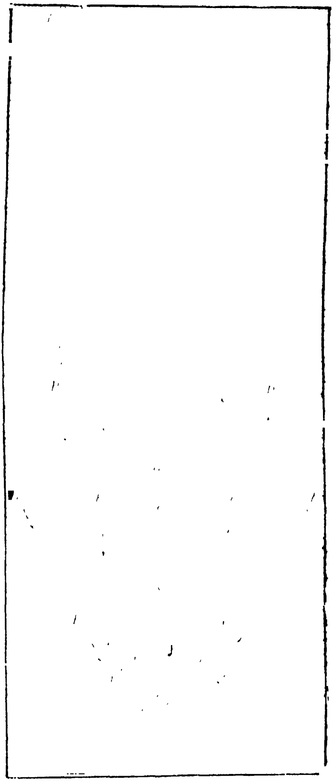
To render these explanations, which are of the greatest interest and importance in relation to the subject of comets, more clearly understood, we have represented, in fig. 1, the forms of a very eccentric ellipse, *a b a' b'*, a parabola *a p p'*, and an hyperbola *a h h'*, having *s* as their common focus, and it will be convenient to explain in the first instance the relative magnitude of some important lines and distances connected with these orbits.

5. Ellipses or ovals vary without limit in their eccentricity. A circle is regarded as an ellipse whose eccentricity is nothing. The orbits of the planets generally are ellipses, but having eccentricities so small that, if described on a large scale in their proper proportions on paper, they would be distinguishable from circles only by measuring accurately the dimensions taken in different directions, and thus ascertaining that they are longer in a certain direction than in another at right angles to it. A very eccentric and oblong ellipse is delineated in fig. 1, of which *a a'* is the major axis. The focus being *s*, the perihelion distance

d is *s a*, and the aphelion distance *d′* is *s a′*, the mean distance *a* being *s c*, or half the major axis.

The curvature of the ellipse continually increases from the mean distance to perihelion, and constantly decreases from perihelion to the mean distance, being equal at equal angular distances from perihelion as seen from the sun.

Fig. 1.



It is evident that if a body move in a very eccentric ellipse, such as that represented in fig. 1, whose plane coincides exactly or nearly with the common plane of the planetary orbits, it may intersect the orbits of several or all of the planets, as it is represented to do in the figure, although its mean distance from the sun may be less than the mean distance of several of those which it thus intersects. The aphelion distance of such a body may, therefore, greatly exceed that of any planet; while its mean distance may be less than that of the more distant planets.

6. The form of a parabolic orbit having the same perihelion distance as the elliptic orbit is represented at *a p p*, in fig. 1. This orbit consists of two indefinite branches, similar in form, which unite at perihelion *a*. Departing from this point on opposite sides of the axis *a a′*, their curvature regularly and rapidly decreases, being equal at equal distances from perihelion. The two branches have a constant tendency to assume the direction and form of two straight lines parallel to the axis *a a′*. To actual parallelism, and still less to convergence, these branches, however, never attain, and consequently they can never reunite. They extend, in fine, like parallel straight lines, to an unlimited

distance, without ever reuniting, but assuming directions when the distance from the focus bears a high ratio to the perihelion distance, which are practically undistinguishable from parallelism.

One parabolic orbit differs from another in its perihelion distance. The less this distance is, the less will be the separation at a given distance from *s* between the parallel directions to which the indefinite branches *p p'* tend. This distance may have any magnitude. The body in its perihelion may graze the surface of the sun, or may pass at a distance from it greater than that of the most remote of the planets, so that, although it be subject to solar attraction, it would in that case never enter within the limits of the solar system at all.

A body moving in such an orbit, therefore, would not make, like one which moves in an ellipse, a succession of revolutions round the sun; nor can the term periodic time be applied at all to its motion. It enters the system in some definite direction, such as *p' p*, as indicated by the arrow from an indefinite distance. Arriving within the sensible influence of solar gravitation, the effects of this attraction are manifested in the curvation of its path, which gradually increases as its distance from the sun decreases, until it arrives at perihelion, where the attractive force, and consequently the curvature, attain their maxima. The extreme velocity which the body attains at this point produces, in virtue of the inertia of the moving mass, a centrifugal force, which counteracts the gravitation, and the body, after passing perihelion, begins to retreat; the solar gravitation and the curvature of its path decreasing together, until it issues from the system in a direction *p p'*, as indicated by the arrows, which is nearly a straight line, and parallel to that in which it entered. In such an orbit a body therefore visits the system but once. It enters in a certain direction from an indefinite distance, and, passing through its perihelion, issues in a parallel direction, passing to an unlimited distance, never to return.

7. Hyperbolic orbits, like the parabolas, consist of two indefinite branches, which unite at perihelion, which at equal distances from perihelion have equal curvatures, and which, as the distance from perihelion increases, approach indefinitely in direction and form to straight lines, but, unlike the parabolic orbits, the straight lines to whose direction the two branches approximate are divergent and not parallel.

Such an orbit having the same perihelion distance as the ellipse and parabola, is represented by *a h h'*, fig. 1.

The parabola is included between the ellipse and hyperbola.

8. When the theory of gravitation was first propounded by its

illustrious author, no other bodies, save the planets and satellites then discovered, were known to move under the influence of such a central attraction. These bodies, however, supplied no example of the play of that celebrated theory in its full latitude. They obeyed, it is true, its laws, but they did much more. They displayed a degree of harmony and order far exceeding what the law of gravitation exacted. Permitted by that law to move in any of the three classes of conic sections, their paths were exclusively elliptical; permitted to move in ellipses infinitely various in their eccentricities, they moved exclusively in such as differed almost insensibly from circles; permitted to move at distances subordinated to no regular law, they moved in a series of orbits at distances increasing in a regular progression; permitted to move at all conceivable angles with the plane of the ecliptic, their paths are inclined to it at angles limited in general to a few degrees; permitted, in fine, to move in either direction, they all agreed in moving in the direction in which the earth moves in its annual course.

Accordance so wondrous, and order so admirable, could not be fortuitous, and, not being enjoined by the conditions of the law of gravitation, must either be ascribed to the immediate dictates of the Omnipotent Architect of the universe above all general laws, or to some general laws superinduced upon gravitation, which had escaped the sagacity of the discoverer of that principle. If the former supposition were adopted, some bodies, different in their physical characters from the planets, primary and secondary, playing different parts and fulfilling different functions in the economy of the universe, might still be found, which would illustrate the play of gravitation in its full latitude, sweeping round the sun in all forms of orbit, eccentric, parabolic, and hyperbolic, in all planes, at all distances, and indifferently in both directions. If the latter supposition were accepted, then no other orbit, save ellipses of small eccentricity, with planes coinciding nearly with that of the ecliptic, would be physically possible.

9. The theory of gravitation had not long been promulgated, nor as yet been generally accepted, when the means of its further verification were sought in the motion of comets. Hitherto these bodies had been regarded as exceptional and abnormal, and as being exempt altogether from the operation of the law and order which prevailed in a manner so striking among the members of the solar system. So little attention had been given to comets that it had not been certainly ascertained whether they were to be classed as meteoric or cosmical phenomena; whether their theatre was the regions of the atmosphere, or the vast spaces in which the great bodies of the universe move. Their apparent positions in

the heavens on various occasions of the appearances of the most conspicuous of them had nevertheless been from time to time for some centuries observed and recorded with such a degree of precision as the existing state of astronomical science permitted; and even when their places were not astronomically ascertained, the date of their appearance was generally preserved in the historic records, and in many cases the constellations through which they passed were indicated, so that the means of obtaining at least a rude approximation to their position in the firmament were thus supplied.

10. Such observations, vague, scattered, and inexact as they were, supplied, however, data by which, in several cases, it was possible to compute the real motion of these bodies through space, their positions in relation to the sun, the earth, and the planets, and the paths they followed in moving through the system, with sufficiently approximate accuracy to conclude with certainty that they were one or other of the conic sections, the place of the sun being the focus.

This was sufficient to bring these bodies under the general operation of the attraction of gravitation.

It still remained, however, to determine more exactly the specific character of these orbits. Are they ellipses more or less eccentric? or parabolas? or hyperbolas?—Any of the three classes of orbits would, as has been shown, be equally compatible with the law of gravitation.

11. It might be supposed that the same course of observation as that by which the orbit of a planet is traced would be applicable equally to comets. Many circumstances, however, attend this latter class of bodies, which render such observations impossible, and compel the astronomer to resort to other means to determine their orbits.

A spectator stationed upon the earth keeps within his view each of the other planets of the system throughout nearly the whole of its course. Indeed, there is no part of the orbit of any planet in which, *at some time or other*, it may not be seen from the earth. Every point of the path of each planet can therefore be observed; and, although without waiting for such observation, its course might be determined, yet it is material here to attend to the fact, that the whole orbit may be submitted to direct observation. The different planets, also, present peculiar features by which each may be distinguished. Thus, as has been explained, they are observed to be spherical bodies of various magnitudes. Their surfaces are marked by peculiar modes of light and shade, which, although variable and shifting, still, in each case, possess some prevailing and permanent characters by which the identity of the

object may be established, even were there no other means of determining it.

Unlike planets, comets do not present to us those individual characters above mentioned, by which their identity may be determined. None of them have been satisfactorily ascertained to be spherical bodies, nor indeed to have any definite shape. It is certain that many of them possess no solid matter, but are masses consisting of some nearly transparent substances; others are so surrounded with this apparently vaporous matter, that it is impossible, by any means of observation which we possess, to discover whether this vapour enshrouds within it any solid mass. The same vapour which thus envelopes the body (if such there be within it) also conceals from us its features and individual character. Even the limits of the vapour itself, if vapour it be, are subject to great change in each individual comet. Within a few days they are sometimes observed to increase or diminish some hundred-fold. A comet appearing at distant intervals presents, therefore, no very obvious means of recognition. A like extent of surrounding vapour would evidently be a fallible test of identity; and not less inconclusive would it be to infer diversity from a different extent of nebulosity.

If a comet, like a planet, revolved round the sun in an orbit nearly circular, it might be seen in every part of its path, and its identity might thus be established independently of any peculiar characters in its appearance. But such is not the course which comets are observed to take.

In general a comet is visible only throughout an arc of its orbit, which extends to a certain limited distance on each side of its perihelion. It first becomes apparent at some point of its path, such as g, g' or g'', fig. 1; it approaches the sun and disappears after it passes a corresponding point g, g' or g'' in departing from the sun. The arc of its orbit in which alone it is visible would therefore be $g\ a\ g$, $g'\ a\ g'$, or $g''\ a\ g''$.

If this arc, extending on either side of perihelion, could always be observed with the same precision as are the planetary orbits, it would be possible, by the properties of the conic sections, to determine not only the general character of the orbit, whether it be an ellipse, or parabola, or an hyperbola, but even to ascertain the individual curve of the one kind or the other in which the comet moves, so that the course it followed before it became visible, as well as that which it pursues after it ceases to be visible, would be as certainly and precisely known as if it could be traced by direct observation throughout its entire orbit.

12. If it be ascertained that the arc in which the comet moves while it is visible is part of an hyperbola, such as $g\ a\ g$, it will be

inferred that the comet coming from some indefinitely distant region of the universe, has entered the system in a certain direction, $h' h$, which can be inferred from the visible arc $g\ a\ g$, and that it must depart to another indefinitely distant region of the universe following the direction $h\ h'$, which is also ascertained from the visible arc $g\ a\ g$.

If, on the other hand, it be ascertained that the visible arc, such as $g'\ a\ g'$, be part of a parabola, then, in like manner by the properties of that curve, it will follow that it entered the system coming from an indefinitely distant region of the universe in a certain direction, $p'\ p$, which can be inferred from the visible arc $g'\ a\ g'$, and that after it ceases to be visible, it will issue from the system in another determinate direction, $p\ p'$, parallel to that by which it entered.

The comet, in neither of these cases, would have a periodic character. It would be analogous to one of those occasional meteors which are seen to shoot across the firmament never again to reappear. The body arriving from some distant region, and coming, as would appear, fortuitously within the solar attraction, is drawn from its course into the hyperbolic or parabolic path, which it is seen to pursue, and escapes from the solar attraction, issuing from the system never to return. The phenomenon would in each case be occasional, and, in a certain sense, accidental, and the body could not be said properly to belong to the system. So far as relates to the comet itself, the phenomenon would consist in a change of the direction of its course through the universe, operated by the temporary action of solar gravitation upon it.

13. But the case is very different, the tie between the comet and the system much more intimate, and the interest and physical importance of the body transcendently greater when the arc, such as $g''\ a\ g''$, proves to be part of an ellipse. In that case, the invisible part of the orbit being inferred from the visible, the major axis $a\ a'$ would be known. The comet would possess the periodic character, making successive revolutions like the planets, and returning to perihelion a after the lapse of its proper periodic time, which could be inferred by the harmonic law from the magnitude of its major axis.

Such a body would then not be, like those which follow hyperbolic or parabolic paths, an occasional visit to the system, connected with it by no permanent relation, and subject to solar gravitation only accidentally and temporarily. It would, on the contrary, be as permanent, if not as strictly regular, a member of the system as any of the planets, though invested, as will presently appear, with an extremely different physical character.

It will therefore be easily conceived with what profound interest

comets were regarded before the theory of gravitation had been yet firmly established or generally accepted, and while it was, so to speak, upon its trial. These bodies were, in fact, looked for as the witnesses whose testimony must decide its fate.

14. Difficulties, however, which seemed almost insurmountable, opposed themselves to a satisfactory and conclusive analysis of their motions. Many causes rendered the observations upon their apparent places few in number and deficient in precision. The arcs $g\ a\ g$, $g'\ a\ g'$, and $g''\ a\ g''$ of the three classes of orbit in any of which they might move without any violation of the law of gravitation were very nearly coincident in the neighbourhood of the place of perihelion a. It was, for example, in almost all the cases which presented themselves, possible to conceive three different curves, an eccentric ellipse, such as $a\ b\ a'\ b'$, a parabola, such as $p'\ p\ a$, and an hyperbola, such as $h'\ h\ a$, so related that the arcs $g\ a\ g$, $g'\ a\ g'$, and $g''\ a\ g''$, would not deviate one from another to an extent exceeding the errors inevitable in cometary observations. Thus any one of the three curves within the limits of the visible path of the comet might with equal fidelity represent its course. In such cases, therefore, it was impossible to infer, from the observations alone, whether the comet belonged to the class of hyperbolic or parabolic bodies, which have no periodic character, or to the elliptic, which has.

15. The character of periodicity itself, which belongs exclusively to elliptic orbits, supplied the means of surmounting this difficulty. If any observed comet have an elliptic motion, it must return to perihelion after completing its revolution, and it must have been visible on former returns to that position. Not only ought it to be expected, therefore, that such a comet would re-appear in future after absences of equal duration (depending on its periodic time), but that its previous returns to perihelion would be found by searching among the recorded appearances of such objects for any, the dates of whose appearance might correspond with the supposed period, and whose apparent motions, if observed, might indicate a real motion in an orbit, identical or nearly so with that of the comet in question.

If the motion of such a body were not affected by any other force except the solar attraction, it would re-appear after each successive revolution at exactly the same point; would follow, while visible, exactly the same arc $g''\ a\ g''$; would move in the same plane, inclined at the same angle to the ecliptic, the nodes retaining the same places; and would arrive at its perihelion at exactly the same point a, and after exactly equal intervals.

Now, although the disturbing actions of the planets near which it might pass, in departing from and returning to the sun, must

be expected to be much more considerable than when one planet acts upon another, as well because of the extreme comparative lightness of the comet, as of the great eccentricity of its orbit, which sometimes actually or nearly intersects the paths of several planets, and especially those of the larger ones, yet still such planetary attractions are *only* disturbances, and cannot be supposed to efface that character which the orbit receives from the predominant force of the immense mass of the sun. While therefore we may be prepared for the possibility, and even the probability, that the same periodic comet on the occasion of its successive re-appearances, may follow a path $g'' a g''$ in passing to and from its perihelion, differing to some extent from that which it had followed on previous appearances, yet in the main such differences cannot, except in rare and exceptional cases, be very considerable, and for the same reason the intervals between its successive periods, though they may differ, cannot be subject to any very great variation.

16. If then, on examining the various comets whose appearances have been recorded, and whose places while visible have been observed, and on computing from the apparent places the arc of the orbit through which they moved, it be found that two or more of them, while invisible, moved in the same path, the presumption will be that these were the same body re-appearing after having completed its motion in an elliptic orbit; nor should this presumption of identity be hastily rejected because of the existence of any discrepancies between the observed paths, or any inequality of the intervals between its successive re-appearances, so long as such discrepancies can fairly be ascribed to the possible disturbances produced by planets which the comet might have encountered in its path.

17. Many comets, however, have been *recorded*, but not *observed*. Historians have mentioned, and even described, their appearances, and in some cases have indicated the chief constellations through which such bodies passed, although no observations of their apparent places have been transmitted by which any close approximation to their actual paths could be made. Nevertheless, even in these cases, some clue to their identification is supplied. The intervals between their appearances alone is a highly probable test of identity. Thus if comets were regularly recorded to have appeared at intervals of fifty years (no circumstance affording evidence of the diversity of these objects), they might be assumed, with a high degree of probability, to be the successive returns of an elliptic comet having that interval as its period.

18. The appearances of about 400 comets had been recorded in the annals of various countries before the end of the seventeenth

century, the epoch signalised by the discoveries and researches of Newton. In most cases, however, the only circumstance recorded was the appearance of the object, accompanied in many instances with details bearing evident marks of exaggeration respecting its magnitude, form, and splendour. In some few cases, the constellations through which the object passed successively, with the necessary dates, are mentioned, and in some, fewer still, observations of a rough kind have been handed down. From such scanty data, eagerly sought for in the works preserved in different countries, sufficient materials have been collected for the computation, with more or less approximation, of the elements of the orbits of about sixty of the 400 comets above mentioned.

Since the time of Newton, Halley, and their contemporaries, observers have been more active, and have had the command of instruments of considerable and constantly increasing power; so that every comet which has been visible from the northern hemisphere of the earth since that time, has been observed with continually increasing precision, and data have been in all cases obtained, by which the elements of the orbits have been calculated. Since the year 1700, accordingly, about 140 have been observed, the elements of the orbits of which have been ascertained with great precision.

It appears, therefore, that of the entire number of comets which have appeared in the firmament, the orbits of about 200 have been ascertained. Of this number forty have been ascertained, some conclusively, others with more or less probability, to revolve in elliptic orbits.

Seven have passed through the system in hyperbolas, and consequently will not visit it again, unless they be thrown into other orbits by some disturbing force.

One hundred and sixty have passed through the system either in parabolic orbits, or in ellipses of such extreme eccentricity as to be undistinguishable from parabolas by any data supplied by the observations.

II.—ELLIPTIC COMETS REVOLVING WITHIN THE ORBIT OF SATURN.

19. In 1818, a comet was observed at Marseilles, on the 26th of November, by M. Pons. In the following January, its path being calculated, M. Arago immediately recognised it as identical with one which had appeared in 1805. Subsequently, M. Encké of Berlin succeeded in calculating its entire orbit—inferring the invisible from the visible part—and found that its period was

about 1200 days. This calculation was verified by the fact of its return in 1822, since which time the comet has gone by the name of *Encké's comet*, and returned regularly.

It may be asked, How it could have happened that a comet which made its revolution in a period so short as three years and a quarter, should not have been observed until so recent an epoch as 1818? This is explained by the fact that the comet is so small, and its light so feeble even when in the most favourable position, that it can only be seen with the aid of the telescope, and not even with this except under certain conditions which are not fulfilled on the occasion of every perihelion passage. Nevertheless, the comet was observed on three former occasions, and the general elements of its path recorded, although its elliptic, and consequently periodic character, was not recognised.

On comparing, however, the elements then observed with those of the comet now ascertained, no doubt can be entertained of their identity.

20. In the following table are given the elements of the orbit of this comet, as computed from the observations made upon it at each of its three appearances in 1786, 1795, and 1805, before its periodic character was discovered, and at its eleven subsequent appearances up to 1852.

TABLE I.

Elements of the Orbit of Encké's Comet to 1852.

	Mean Distance, Earth's = 1.	Eccentricity.	Perihelion Distance.	Aphelion Distance.	Longitude of Perihelion.			Longitude of Ascending Node.			Inclination.			Time of Perihelion Passage.		
	a	e	$d'=a\times(1-e)$	$d''=a\times(1+e)$	ϖ			ν			i					
					°	′	″	°	′	″	°	′	″		h.	m.
1786	2·2080	0·8484	0·3348	4·0812	156	38	0	334	8	0	13	36	0	Jan. 30.	21	7
1795	2·2130	0·8489	0·3344	4·0916	156	41	20	334	39	22	13	42	30	Dec. 21.	10	44
1805	2·2131	0·8462	0·3404	4·0860	156	47	24	334	20	10	13	33	30	Nov. 21.	12	9
1819	2 2141	0·8486	0·3353	4·0929	156	59	12	334	33	19	13	36	54	Jan. 27.	6	18
1822	2·2244	0·8445	0·3460	4.1028	157	11	44	334	25	9	13	20	17	May 23.	23	16
1825	2·2233	0·8449	0·3449	4·1017	157	14	31	334	27	30	13	21	24	Sept. 16.	6	43
1829	2·2239	0·8446	0·3455	4·1023	157	17	53	334	29	32	13	20	34	Jan. 9.	18	3
1832	2 2219	0·8454	0·3435	4·1003	157	21	1	334	32	9	13	22	9	May 23.	23	34
1835	2·2227	0·8450	0·3444	4·1010	157	23	29	334	34	59	13	21	15	Aug. 26.	8	49
1838	2·2222	0 8452	0·3440	4·1004	157	27	4	334	36	41	13	21	28	Dec. 19.	0	27
1842	2·2229	0·8448	0·3450	4·0998	157	29	27	234	39	10	13	20	26	April 12.	0	35
1845	2·2215	0·8474	0.3381	4·1049	157	44	21	334	19	34	13	7	34	Aug. 9.	15	11
1848	2·2147	0·8478	0·3371	4·0923	157	47	8	334	22	12				Nov. 26.	3+	0
1852	2·2152	0·8477	0·3374	4·0930	157	51	2	334	23	21	13	7	55	March 14.	20	

M. T. B.

The motion of this comet is direct; and its period in 1852 was 3·29616 years, which is subject to a slight variation.

It is evident that between 1786 and 1795 there were two,

between 1795 and 1805 two, and, in fine, between 1805 and 1819 three, unobserved returns to perihelion.

It appears, therefore, that, excepting the oval form of the orbit, the motion of this body differs in nothing from that of a planet whose mean distance from the sun is that of the nearest of the planetoids. Its eccentricity is such, however, that when in perihelion it is within the orbit of Mercury, and when in aphelion it is outside the most distant of the planetoids, and at a distance from the sun equal to four-fifths of that of Jupiter.

21. A fact altogether anomalous in the motions of the bodies of the solar system, and indicating a consequence of the highest physical importance, has been disclosed in the observation of the motion of this comet. It has been found that its periodic time, and consequently its mean distance, undergoes a slow, gradual, and apparently regular decrease. The decrease is small, but not at all uncertain. It amounted to about a day in ten revolutions, a quantity which could not by any means be placed to the account either of errors of observation or of calculation; and, besides, this increase is incessant, whereas errors would affect the result sometimes one way and sometimes the other. The period of the comet between 1786 and 1795 was $1208\frac{1}{9}$ days; between 1795 and 1805 it was $1207\frac{9}{10}$ days; between 1805 and 1819 it was $1207\frac{4}{10}$ days; in 1845 it was $1205\frac{1}{4}$ days; and, in fine, in 1852 it was 1204 days.

The magnitude of the orbit thus constantly decreasing (for the cube of its greater axis must decrease in the same proportion as the square of the period), the actual path followed by the comet must be a sort of elliptic spiral, the successive coils of which are very close together, every successive revolution bringing the comet nearer and nearer to the sun.

Such a motion could not arise from the disturbing action of the planets. These forces have been taken strictly into account in the computation of the ephemerides of the comet, and there is still found this residual phenomenon, which cannot be placed to their account, but which is exactly the effect which would arise from any physical agency by which the tangential motion of the comet would be feebly but constantly resisted. Such an agency, by diminishing the tangential velocity, would give increased efficacy to the solar attraction, and, consequently, increased curvature to the comet's path; so that, after each revolution, it would revolve at a less distance from the centre of attraction.

22. It is evident that a resisting medium, such as the luminiferous ether * is assumed to be in the hypothesis which forms

* See "Hand-Book of Astronomy," § 1225.

the basis of the undulatory theory of light, would produce just such a phenomenon, and accordingly the motion of this comet is regarded as a strong evidence tending to convert that hypothetical fluid into a real physical agent.

It remains to be seen whether a like phenomenon will be developed in the motion of other periodic comets. The discovery of these bodies, and the observation of their motions, are as yet too recent to enable astronomers, notwithstanding their greatly multiplied number, to pronounce decisively upon it.

23. If the existence of this resisting medium should be established by its observed effects on comets in general, it will follow, that, after the lapse of a certain time (many ages, it is true, but still a definite interval), the comets will be successively absorbed by the sun, unless, as is not improbable, they should be previously vaporised by their near approach to the solar fires, and should thus be incorporated with his atmosphere.

In the efforts by which the human mind labours after truth, it is curious to observe how often that desired object is stumbled upon by accident, or arrived at by reasoning which is false. One of Newton's conjectures respecting comets was, that they are "the aliment by which suns are sustained;" and he therefore concluded that these bodies were in a state of progressive decline upon the suns, round which they respectively swept; and that into these suns they from time to time fell. This opinion appears to have been cherished by Newton to the latest hours of his life: he not only consigned it to his immortal writings, but, at the age of eighty-three, a conversation took place between him and his nephew on this subject, which has come down to us. "I cannot say," said Newton, "when the comet of 1680 will fall into the sun; possibly after five or six revolutions; but whenever that time shall arrive, the heat of the sun will be raised by it to such a point, that our globe will be burnt, and all the animals upon it will perish. The new stars observed by Hipparchus, Tycho, and Kepler, must have proceeded from such a cause, for it is impossible otherwise to explain their sudden splendour." His nephew then asked him, "Why, when he stated in his writings that comets would fall into the sun, did he not also state those vast fires they must produce, as he supposed they had done in the stars?" —"Because," replied the old man, "the conflagrations of the sun concern us a little more directly. I have said, however," added he, smiling, "enough to enable the world to collect my opinion."

Fig. 19.—Jan. 24, 1836.

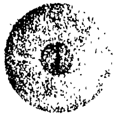


Fig. 20.—Jan. 25, 1836.

Fig. 21.—Jan. 26, 1836.

Fig. 22.—Jan. 27, 1836.

HALLEY'S COMET DEPARTING FROM THE SUN IN 1836.

COMETS.

CHAPTER II.

24. Why like effects are not manifested in the motion of the planets.—25. Corrected estimate of the mass of Mercury.—26. Biela's comet.—27. Possibility of the collision of Biela's comet with the earth.—28. Resolution of Biela's comet into two.—29. Changes of appearance attending the separation.—30. Faye's comet.—31. Reappearance in 1850-1 calculated by M. Le Verrier.—32. De Vico's comet.—33. Brorsen's comet.—34. D'Arrest's comet.—35. Elliptic comet of 1743.—36. Elliptic comet of 1766.—37. Lexell's comet.—38. Analysis of Laplace applied to Lexell's comet.—39. Its orbit before 1767 and after 1770 calculated by his formulæ.—40. Revision of these researches by M. Le Verrier. —41. Process by which the identification of periodic comets may be decided.—42. Application of this process by M. Le Verrier to the comets of Faye, De Vico, and Brorsen, and that of Lexell—their diversity proved.—43. Probable identity of De Vico's comet with the

comet of 1678.—44. Blainplan's comet of 1819.—45. Pons's comet of 1819.—46. Pigott's comet of 1783.—47. Peters's comet of 1846.—48. Tabular synopsis of the orbits of the comets which revolve within Saturn's orbit.—49. Diagram of the orbits.—50. Planetary character of their orbits.—III. Elliptic Comets, whose mean distances are nearly equal to that of Uranus: 51. Comets of long periods first recognised as periodic.—52. Newton's conjectures as to the existence of comets of long periods.—53. Halley's researches.—54. Halley predicts its re-appearance in 1758-9.

24. It may be asked, If the existence of a resisting medium be admitted, whether the same ultimate fate must not await the planets? To this inquiry it may be answered that, within the limits of past astronomical record, the ethereal medium, if it exist, has had no sensible effect on the motion of any planet. That it might have a perceptible effect upon comets, and yet not upon planets, will not be surprising, if the extreme lightness of the comets compared with their bulk be considered. The effect in the two cases may be compared to that of the atmosphere upon a piece of swan's down and upon a leaden bullet moving through it. It is certain that whatever may be the nature of this resisting medium, it will not, for many hundred years to come, produce the slightest perceptible effect upon the motions of the planets.

25. The masses of comets in general are, as will be explained, incomparably smaller than those of the smallest of the planets; so much so, indeed, as to bear no appreciable ratio to them. A consequence of this is, that while the effects of their attraction upon the planets are altogether insensible, the disturbing effects of the masses of the planets upon them are very considerable. These disturbances, being proportional to the disturbing masses, may then be used as measures of the latter, just as the movement of the pith-ball in the balance of torsion supplies a measure of the physical forces to which that instrument is applied.

Encké's comet, near its perihelion, passes near the orbit of Mercury; and when that planet, at the epoch of its perihelion, happens to be near the same point, a considerable and measurable disturbance is manifested in the comet's motion, which being observed, supplies a measure of the planet's mass.

This combination of the motions of the planet and comet took place under very favourable circumstances, on the occasion of the perihelion passage of the comet in 1838, the result of which, according to the calculations of Professor Encké, was the discovery of an error of large amount in the previous estimates of the mass of the planet. After making every allowance for other planetary attractions, and for the effects of the resisting medium, the existence of which it appears necessary to admit, it was inferred

that the mass assigned to Mercury by Laplace was too great in the proportion of 12 to 7.

This question is still under examination, and every succeeding perihelion passage of the comet will increase the data by which its more exact solution may be accomplished.

26. On February 28, 1826, M. Biela, an Austrian officer, observed in Bohemia a comet, which was seen at Marseilles at about the same time by M. Gambart. The path which it pursued, was observed to be similar to that of comets which had appeared in 1772 and 1806. Finally, it was found that this body moved round the sun in an oval orbit, and that the time of its revolution was about 6 years and 8 months. It has since returned at its predicted times, and has been adopted as a member of our system, under the name of Biela's comet.

Biela's comet moves in an orbit whose plane is inclined at a small angle to those of the planets. It is but slightly oval, the length being to the breadth in the proportion of about 4 to 3. When nearest to the sun, its distance is a little less than that of the earth; and when most remote from the sun, its distance somewhat exceeds that of Jupiter. Thus it ranges through the solar system, between the orbits of Jupiter and the earth.

This comet had been observed in 1772 and in 1806; but the elliptic form of its orbit, and consequently its periodicity, was not discovered. Its return to perihelion was predicted and observed in 1832, in 1846, and in 1852; but that which took place in 1838 escaped observation, owing to its unfavourable position and extreme faintness.

A Table, showing the elements of this comet during each of its appearances from 1772 to 1846 inclusive, may be seen by reference to my "Hand-Book of Astronomy."

27. One of the points at which the orbit of Biela's comet intersects the plane of the ecliptic, is at a distance from the earth's orbit less than the sum of the semi-diameters of the earth and the comet. It follows, therefore (2905), that if the comet should arrive at this point at the same moment at which the earth passes through the point of its orbit which is nearest to it, a portion of the globe of the earth must penetrate the comet.

It was estimated on the occasion of the perihelion passage of this comet in 1832, that the semi-diameter of the comet (that body being nearly globular, and having no perceptible tail) was 21000 miles, while the distance of the point at which its centre passed through the plane of the ecliptic, on the 29th October in that year, from the path of the earth was only 18600 miles. If the centre of the earth happened to have been at the point of its orbit nearest to the centre of the comet on that day, the distance

between the centres of the two bodies would have been only 18600 miles, while the semi-diameter of the comet was 21000 miles; and the semi-diameter of the earth being in round numbers 4000 miles, it would follow that in such a contingency the earth would have plunged into the comet to a depth of

$$21000 + 4000 - 18600 = 6400 \text{ miles},$$

a depth exceeding three-fourths of the earth's diameter.

The possibility of such a catastrophe having been rumoured, great popular alarm was excited before the expected return of the comet in 1832. It was, however, shown that on the 29th October the earth would be about five millions of miles from the point of danger, and that, on the arrival of the earth at that point, the comet would have moved to a still greater distance.

28. *Resolution of Biela's comet into two.*—One of the most extraordinary phenomena of which the history of astronomy affords any example, attended the appearance of this comet in 1846. It was on that occasion seen to resolve itself into two distinct comets, which, from the latter end of December, 1845, to the epoch of its disappearance in April, 1846, moved in distinct and independent orbits. The paths of these two bodies were in such optical juxtaposition that both were always seen together in the field of view of the telescope, and the greatest visual angle between their centres did not amount at any time to 10′, the variation of that angle arising principally from the change of direction of the visual line, relatively to the line joining their centres, and to the change of the comet's distance from the earth.

M. Plantamour, director of the Observatory of Geneva, calculated the orbits of these two comets, considered as independent bodies; and found that the real distance between their centres was, subject to but little variation while visible, about thirty-nine semi-diameters of the earth, or two-thirds of the moon's distance. The comets moved on thus side by side, without manifesting any reciprocal disturbing action; a circumstance no way surprising, considering the infinitely minute masses of such bodies.

29. The original comet was apparently a globular mass of nebulous matter, semi-transparent at its very centre, no appearance of a tail being discoverable. After the separation, both comets had short tails, parallel in their direction, and at right angles to the line joining their centres; both had nuclei. From the day of their separation the original comet decreased, and the companion increased, in brightness, until (on the 10th February) they were sensibly equal. After this the companion still increased

in brightness, and from the 14th to the 16th was not only greatly superior in brightness to the original, but had a sharp and star-like nucleus, compared to a diamond spark. The change of brightness was now reversed, the original comet recovering its superiority, and acquiring on the 18th the same appearance as the companion had from the 14th to the 16th. After this the companion gradually faded away, and disappeared previously to the final disappearance of the original comet on 22nd April.

It was observed also that a thin luminous line or arc was thrown across the space which separated the centres of the two nuclei, especially when one or the other had attained its greatest brightness, the arc appearing to emanate from that which for the moment was the brighter.

After the disappearance of the companion, the original comet threw out three faint tails, forming angles of 120° with each other, one of which was directed to the place which had been occupied by the companion.

It is suspected that the faint comet which was observed by Professor Secchi to precede Biela's comet in 1852, may have been the companion thus separated from it, and if so, the separation must be permanent, the distance between the parts being greater than that which separates the earth from the sun.

30. On the 22nd November, 1843, M. Faye, of the Paris Observatory, discovered a comet, the path of which soon appeared to be incompatible with the parabolic character. Dr. Goldschmidt showed that it moved in an ellipse of very limited dimensions, with a period of $7\frac{1}{2}$ years. It was immediately observed as being extraordinary, that, notwithstanding the frequent returns to perihelion which such a period would infer, its previous appearances had not been recorded. M. Faye replied by showing that the aphelion of the orbit passed very near to the path of Jupiter, and that it was possible that the violent action of the great mass of that planet, in such close proximity with the comparatively light mass of the comet, might have thrown the latter body into its present orbit, its former path being either a parabola or an ellipse, with such elements as to prevent the comet from coming within visible distance. M. Faye supported these observations by reference to a more ancient comet, which we shall presently notice, to which a like incident is supposed with much probability, if not certainty, to have occurred.

31. The observations which had been made in 1843, at several observatories, but more especially those made by M. Struve at Pultowa, who continued to observe the comet long after it ceased to be observed elsewhere, supplied to M. Le Verrier the data necessary for the calculation of its motion in the interval between its

perihelion in 1843 and its expected re-appearance in 1850-1, subject to the disturbing action of the planets, and he predicted its succeeding perihelion for the 3rd of April, 1851.

Aided by the formulæ of M. Le Verrier, Lieutenant Stratford calculated a provisional ephemeris in 1850, by which observers might be enabled more easily to detect the comet, which was the more necessary as the object is extremely faint and small, and not capable of being seen except by means of the most perfect telescopes. By means of this ephemeris, Professor Challis, of Cambridge, found the comet on the night of the 28th November very nearly in the place assigned to it in the tables. Two observations only were then made upon it, which, however, were sufficient to enable M. Le Verrier to give still greater precision to his formulæ, by assigning a definite numerical value to a small quantity which before was left indeterminate. Lieutenant Stratford, with the formula thus corrected, calculated a more extensive and exact ephemeris, extending to the last day of March, and published it in January, 1851, in the Nautical Almanack.

The comet, though extremely faint and small, and consequently difficult of observation, continued to be observed by Professor Challis, with the great Northumberland telescope, at Cambridge, and by M. Struve at Pultowa, and it was found to move in exact accordance with the predictions.

32. On the 22nd August, 1844, M. de Vico, of the Roman Observatory, discovered a comet whose orbit was soon afterwards proved by M. Faye to be an ellipse of moderate eccentricity, with a period of about $5\frac{1}{2}$ years. It arrived at its perihelion on the 2nd of September, and continued to be observed until the 7th of December.

33. On the 26th of February, 1846, M. Brorsen, of Kiel, discovered a faint comet, which was soon found to move in an elliptic orbit, with a period of about $5\frac{1}{2}$ years. Its position in the heavens not being favourable, the observations upon it were few, and the resulting elements, consequently, not ascertained with all the precision that might be desired. Its re-appearance on its approach to the succeeding perihelion, was expected from September to November, 1851. It escaped observation, however, owing to its unfavourable position in relation to the sun. Its next perihelion passage will take place in 1857.

34. On the 27th of June, 1851, Dr. d'Arrest, of the Leipsic Observatory, discovered a faint comet, which M. Villarceaux proved to move in an elliptic orbit, with a period of about $6\frac{1}{2}$ years. The next perihelion passage of this comet will take place in the end of 1857, or the beginning of 1858.

35. A revision of the recorded observations of former comets by

the more active and intelligent zeal of modern mathematicians and computers, has led to the discovery of the great probability of several among them having revolved in elliptic orbits, with periods not differing considerably from those of the comets above mentioned. The fact that these comets have not been re-observed on their successive returns through perihelion, may be explained, either by the difficulty of observing them, owing to their unfavourable positions, and the circumstance of observers not expecting their re-appearance, their periodic character not being then suspected; or because they may have been thrown by the disturbing action of the larger planets into orbits such as to keep them continually out of the range of view of terrestrial observers.

Among those may be mentioned a comet which appeared in 1743, and was observed by Zanetti at Bologna; the observations indicate an elliptic orbit, with a period of about $5\frac{1}{3}$ years.

36. This comet, which was observed by Messier, at Paris, and by La Nux, at the Isle of Bourbon, revolved, according to the calculations of Burckhardt, in an ellipse with a period of 5 years.

37. The history of astronomy has recorded one singular example of a comet which appeared in the system, made two revolutions round the sun in an elliptic orbit, and then disappeared, never having been seen either before or since.

This comet was discovered by Messier, in June 1770, in the constellation of Sagittarius, between the head and the northern extremity of the bow, and was observed during that month. It disappeared in July, being lost in the sun's rays. After passing through its perihelion, it re-appeared about the 4th of August, and continued to be observed until the first days of October, when it finally disappeared.

All the attempts of the astronomers of that day failed to deduce the path of this comet from the observations, until six years later, in 1776, Lexell showed that the observations were explained, not, as had been assumed previously, by a parabolic path, but by an ellipse, and one, moreover, without any example at that epoch, which indicated the short period of $5\frac{1}{2}$ years.

It was immediately objected to such a solution, that its admission would involve the consequence that the comet, with a period so short, and a magnitude and splendour such as it exhibited in 1770, must have been frequently seen on former returns to perihelion; whereas no record of any such appearance was found.

To this Lexell replied, by showing that the elements of its orbit, derived from the observations made in 1770, were such, that at its previous aphelion, in 1767, the comet must have passed within a distance of the planet Jupiter fifty-eight times less than its distance from the sun; and that consequently it must then have sustained

an attraction from the great mass of that planet, more than three times more energetic than that of the sun; that consequently it was thrown out of the orbit in which it previously moved, into the elliptic orbit in which it actually moved in 1770; that its orbit previously to 1767 was, according to all probability, a parabola; and, in fine, that consequently moving in an elliptic orbit from 1767 to 1770, and having the periodicity consequent on such motion, it nevertheless moved only for the first time in its new orbit, and had never come within the sphere of the sun's attraction before this epoch.

Lexell further stated, that since the comet passed through its aphelion, which nearly intersected Jupiter's orbit, at intervals of somewhat above $5\frac{1}{2}$ years, and it encountered the planet near that point in 1767, the period of the planet being somewhat above eleven years, the planet after a single revolution, and the comet after two revolutions, must necessarily again encounter each other in 1779; and, that since the orbit was such that the comet must in 1779 pass at a distance from Jupiter 500 times less than its distance from the sun, it must suffer from that planet an action 250 times greater than the sun's attraction, and that therefore it would in all probability be again thrown into a parabolic or hyperbolic path; and if so, that it would depart for ever from our system to visit other spheres of attraction. Lexell, therefore, anticipated the final disappearance of the comet, which actually took place.

In the interval between 1770 and 1779, the comet returned once to perihelion; but its position was such that it was above the horizon only during the day, and could not in the actual state of science be observed.

38. At this epoch analytical science had not yet supplied a definite solution of the problem of cometary disturbances. At a later period the question was resumed by Laplace who, in his celebrated work, the "Mécanique céleste," gave the general solution of the following problem:—

"The actual orbit of a comet being given, what was its orbit before, and what will be its orbit after being submitted to any given disturbing action of a planet near which it passes?"

39. Applying this to the particular case of Lexell's comet, and assuming as data the observations recorded in 1770, Laplace showed that, before sustaining the disturbing action of Jupiter in 1767, the comet must have moved in an ellipse of which the semi-axis major was 13·293, and consequently that its period, instead of being $5\frac{1}{2}$ years, must have been $48\frac{1}{2}$ years; and that the eccentricity of the orbit was such that its perihelion distance would be but very little less than the mean distance of Jupiter,

and that consequently it could never have been visible. It followed also that, after suffering the disturbing action of Jupiter in 1779, the comet passed into an elliptic orbit whose semi-axis major was 7·3, that its period was consequently twenty years, and that its eccentricity was such that its perihelion distance was more than twice the distance of Mars, and that in such an orbit it could not become visible.

40. This investigation was afterwards revised by M. Le Verrier,* which showed that the observations of 1770 were not sufficiently definite and accurate to justify conclusions so absolute. He has shown that the orbit of 1770 is subject to an uncertainty comprised between certain definite limits; that tracing the consequences of this to the positions of the comet in 1767 and 1779, these positions are subject to still wider limits of uncertainty. Thus he shows that, compatibly with the observations of 1770, the comet might in 1779 pass either considerably outside, or considerably inside Jupiter's orbit, or might, as it was supposed to have done, have passed actually within the orbits of his satellites. He deduces in fine the following general conclusions:—

1. That if the comet had passed within the orbits of the satellites, it must have fallen down upon the planet and coalesced with it; an incident which he thinks highly improbable, though not absolutely impossible.

2. The action of Jupiter may have thrown the comet into a parabolic or hyperbolic orbit, in which case it must have departed from our system altogether, never to return, except by the consequence of some disturbance produced in another sphere of attraction.

3. It may have been thrown into an elliptic orbit, having a great axis and long period, and so placed and formed that the comet could never become visible; a supposition within which comes the solution of Laplace.

4. It may have had merely its elliptic elements more or less modified by the action of the planet, without losing its character of short periodicity; a result which M. Le Verrier thinks the most probable, and which would render it possible that this comet may still be identified with some one of the many comets of short period, which the activity and sagacity of observers are every year discovering.

To facilitate such researches, M. Le Verrier has given a Table, including all the possible systems of elliptic elements of short period which the comet could have assumed, subject to the dis-

* See Mém. Acad. des Sciences, 1847, 1848.

turbing action of Jupiter in 1779, and taking the observations of 1770 within their possible limits of error.

He further demonstrates, that the orbit in which the comet moved antecedently to the disturbing action of Jupiter upon it in 1767, not only could not have been a parabola or hyperbola, but must have been an ellipse, whose major axis was considerably less than that which Laplace deduced from the insufficient observations of Messier. He shows that, before that epoch, the perihelion distance of the comet could not, under any possible supposition, have exceeded three times the earth's mean distance, and most probably was included between $1\frac{1}{2}$ and 2 times that distance; and that the semi-axis major of the orbit could not have exceeded $4\frac{1}{2}$ times the earth's mean distance, a magnitude 3 times less than that assigned to it by the calculations of Laplace.

41. It must not, however, be supposed that it is sufficient to compare the actual elements of each periodic comet thus discovered, with the elements given in the table of M. Le Verrier, and to infer the absence of identity from their discordance. Such an inference would only be rendered valid by showing, that in past ages, the comet in question had suffered no serious disturbing action by which the elements of its orbit could be considerably changed. To decide the question a much more laborious and difficult process must be encountered: a process from which the untiring spirit of M. Le Verrier has not shrunk. It is necessary, in fine, to the satisfactory and conclusive solution of such a problem, that the periodic comet in question should be traced back through all its previous revolutions up to 1779, that all the disturbances which it suffered from the planets which it encountered in that interval be calculated and ascertained, and that by such means the orbit which it must have had previous to such disturbances, in 1779, be determined. Such orbit would then be compared with the table of possible orbits of Lexell's comet, as given by M. Le Verrier; and if it were found to be identical with any of them, the identity of the comet in question with that of Lexell, would be inferred with the highest degree of probability; but if, on the other hand, such discrepancies were found to prevail as must exceed all supposable errors of observation or calculation, the diversity of the comets would follow.

42. M. Le Verrier has applied these principles to the comets of Faye, De Vico, and Brorsen; tracing back their histories during their unseen motions for three-quarters of a century, and ascertaining the effects of the disturbing actions which they must severally have sustained from revolution to revolution, until he

brought them to the epoch of 1779. On comparing the orbits thus determined with those of the table of possible orbits of Lexell's comet, he has shown that none of them can be identical with it, however strongly some of the elements of their present orbits may raise such a presumption.

43. The comet of De Vico having presented striking analogies with a comet which was observed by Tycho Brahe and Rothmann in 1585, and one observed by La Hire in 1678, M. Le Verrier has applied like principles to the investigation of these questions.

MM. Laugier and Mauvais observed that the elements of De Vico's comet presented such a resemblance to that of Tycho Brahe, as almost to decide the question of their identity. M. Le Verrier tracing back the comet of De Vico to 1585, has shown that its orbit at that epoch was so different from that of the comet of Tycho, as to be incompatible with any plausible inference of their identity.*

He has shown, however, by like reasoning, that there is a high degree of probability that the comet of De Vico is identical with that observed by La Hire in 1678.

44. M. Blainplan discovered a comet at Marseilles on the 28th November, 1819, which was observed at Milan until 25th January, 1820. The observations reduced and calculated by Prof. Encké gave an elliptic orbit with a period a little short of five years. Clausen conjectures that this comet may be identical with that of 1743. It has not been seen since 1820.

45. A comet was discovered by M. Pons on June 12th, 1819, which was observed until July 19th. Prof. Encké assigned to it an elliptic orbit, with a period of $5\frac{1}{2}$ years.

46. A comet, discovered by Mr. Pigott at New York in 1783, was shown by Burckhardt to have an elliptic orbit, with a period of $5\frac{1}{2}$ years.

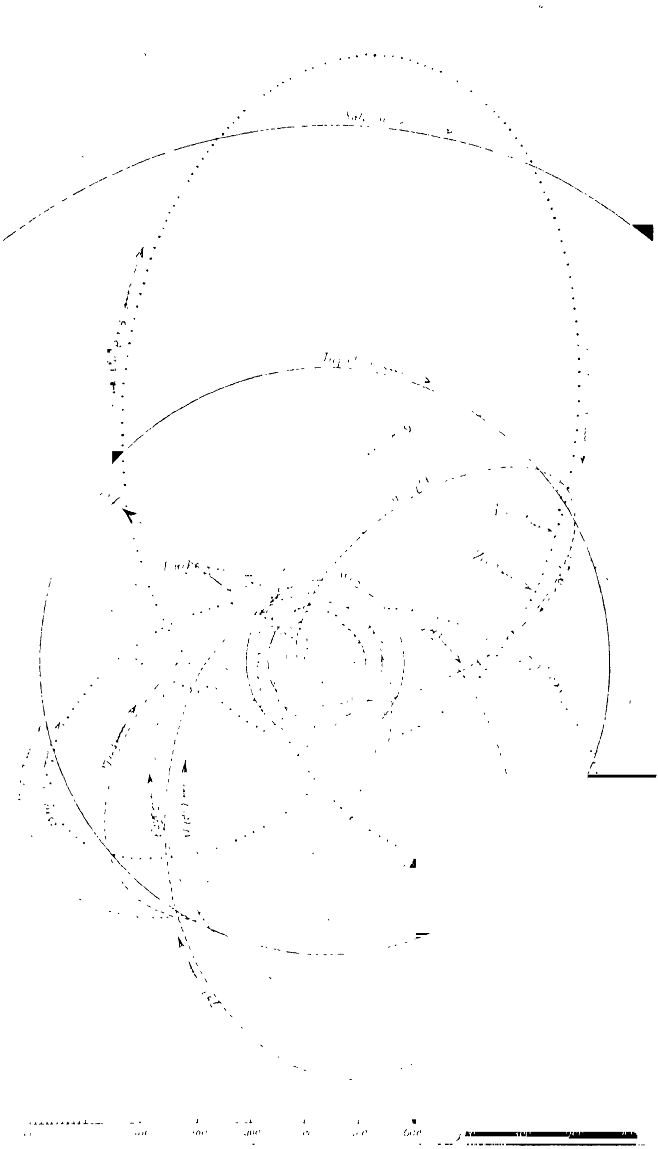
47. On the 26th June, 1846, a comet was discovered at Naples by M. Peters, which was subsequently observed at Rome by De Vico, and continued to be seen until 21st July. An elliptic orbit is assigned to this comet, with a period of from thirteen to sixteen years, some uncertainty attending the observations. The reappearance of this comet may be expected in 1859, 1860.

48. A synoptical Table, showing the elements of the elliptic comets above described, may be seen by a reference to my "Hand-Book of Astronomy."

49. In fig. 2 (page 172), the orbits of these thirteen comets brought to a common plane, are represented roughly but in their

* Mém. Acad. des Sciences, 1847.

Fig. 2.



proper proportions and relative positions, so as to exhibit to the eye their several ellipticities, and the relative directions of their axes.* All these bodies, without one exception, revolve in the common direction of the planets.

50. It is not alone, however, in the direction of their motions that the orbits of these bodies have an analogy to those of the planets. Their inclinations, with one exception, are within the limits of those of the planets. Their eccentricities, though incomparably greater than those of the planets, are, as will presently appear, incomparably less than those of all other comets yet discovered. Their mean distances and periods (with the exception of the last two in the Table just referred to) are within the limits of those of the planetoids.

The comparison of the numbers given in this Table with those in the Tables of the elements of other elliptic comets, and the comparison of the diagrams of their orbits with those of others, will show in a striking manner, to how great an extent the orbits of this group of comets possess the planetary character. Besides moving round the sun in the common direction, their inclinations, with a single exception, are within the limits of those of the planets. It is true that their eccentricities have an order of magnitude much greater; but on the other hand, it will be seen presently that they are incomparably less than the eccentricities of all other periodic comets yet discovered. Their mean distances and periods place them in direct analogy with the planetoids.

Moderate as are the eccentricities as compared with those of other comets, they are sufficiently great to impart a decided oval form to the orbits, and to produce considerable differences between the perihelion and aphelion distances, as will be apparent by inspecting the Table. It appears that while the perihelion of Encké's comet lies within the orbit of Mercury, its aphelion lies outside the orbit of the most remote of the planetoids, and not far within that of Jupiter. The perihelion of Biela's comet, in like manner, lies between the orbits of the earth and Venus, while its aphelion lies outside that of Jupiter. In the case of Faye's comet, the least eccentric of the group, the perihelion lies near the orbit of Mars, and the aphelion outside that of Jupiter.

It must be remembered that the elliptic form of these orbits has only been verified by observations on the successive returns to perihelion of the first five comets in the Table. The elliptic elements of the others may, so far as is at present known, have been effaced by disturbing causes.

* In the diagram, to prevent confusion, the orbits of the different comets are indicated by dotted or broken lines of different kinds.

The angular motions at the mean and extreme distances from the sun have been computed by the formulæ

$$a = \frac{1,296000}{365 \cdot 25 \times P}, \qquad a' = a \times \frac{a^2}{d'^2}, \qquad a'' = \times a \frac{a^2}{d''^2}.$$

In which a represents the mean angular velocity, a' the greatest, and a'', the least; d' the perihelion, and d'' the aphelion distances. P is the periodic time of the comet, and a the mean distance. The same numbers which express these angular motions, also express in all cases the intensities of solar light and heat in the several positions of the comet; and also the apparent motion of the sun, as seen from the comet; and a comparison of these with the corresponding numbers related to any of the planets, will illustrate in a striking manner how different are the physical conditions by which these two classes of bodies are affected; and this will be more and more striking, when the other groups of comets have been noticed.

Taking the comet of Encké as an example, it appears that while its mean daily motion is 1076″ or 18′, its motion in aphelion is only 5′, and in perihelion nearly 13°. Its motion in perihelion, the light and heat it receives from the sun, and the apparent motion of the sun as seen from it, are therefore severally more than 150 times greater in perihelion than in aphelion.

III.—ELLIPTIC COMETS, WHOSE MEAN DISTANCES ARE NEARLY EQUAL TO THAT OF URANUS.

51. It might be expected, that comets moving in elliptic orbits of small dimensions, and consequently having short periods, would have been the first in which the character of periodicity would be discovered. The comparative frequency of their returns to those positions near perihelion, where alone bodies of this class are visible from the earth, and the consequent possibility of verifying the fact of periodicity, by ascertaining the equality of the intervals between their successive returns to the same heliocentric position, to say nothing of the more distinctly elliptic form of the arcs of their orbits in which they can be immediately observed, would afford strong ground for such an expectation; nevertheless in this case, as has happened in so many others in the progress of physical knowledge, the actual results of observation and research have been directly contrary to such an anticipation; the most remarkable case of a comet of large orbit, long period, and rare returns, being the first, and those of small orbits, short

periods, and frequent returns, the last whose periodicity has been discovered.

52. It is evident that the idea of the possible existence of comets with periods shorter than those of the more remote planets, and orbits circumscribed within the limits of the solar system, never occurred to the mind either of Newton or any of his contemporaries or immediate successors.

In the third book of his PRINCIPIA, he calls comets a species of planets, revolving in elliptic orbits of a very oval form. But he continues, "I leave to be determined by others the transverse diameters and periods, by comparing comets which return *after long intervals of time* to the same orbits."

It is interesting to observe the avidity with which minds of a certain order snatch at such generalisations, even when but slenderly founded upon facts. These conjectures of Newton were soon after adopted by Voltaire: "Il y a quelque apparence," says he, in an essay on comets, "qu'on connaîtra un jour un certain nombre de ces autres planètes qui sous le nom de comètes tournent comme nous autour du soleil, mais il ne faut pas espérer qu'on les connaissent toutes."

And again, elsewhere, on the same subject:—

> "Comètes, que l'on craint à l'égal du tonnerre,
> Cessez d'épouvanter les peuples de la terre :
> Dans une ellipse immense achevez votre cours,
> Remontez, descendez près de l'astre des jours."

53. Extraordinary as these conjectures must have appeared at the time, they were soon strictly realised. Halley undertook the labour of examining the circumstances attending all the comets previously recorded, with a view to discover whether any, and which of them, appeared to follow the same path. He found that a comet which had been observed by himself, by Newton, and their contemporaries in 1682, followed a path while visible, which coincided so nearly with those of comets which had been observed in 1607, and in 1531, as to render it extremely probable, that these objects were the same identical comet, revolving in an elliptic orbit of such dimensions, as to cause its return to perihelion at intervals of 75—76 years.

The comet of 1682 had been well observed by La Hire, Picard, Hevelius, and Flamstead, whose observations supplied all the data necessary to calculate its path while visible. That of 1607 had been observed by Kepler and Longomontanus; and that of 1531, by Pierre Apian at Ingolstadt, the observations in both cases being also sufficient for the determination of the path of the body, with all the accuracy necessary for its identification.

54. Of the identity of the paths while visible on each of these appearances Halley entertained no doubt, and announced to the world the discovery of the elliptic motion of comets, as the result of combined observation and calculation, and entitled to as much confidence as any other consequence of an established physical law; and predicted the re-appearance of this body, on its succeeding return to perihelion in 1758-9. He observed, however, that as in the interval between 1607 and 1682 the comet passed near Jupiter, its velocity must have been augmented, and consequently its period shortened by the action of that planet. This period, therefore, having been only seventy-five years, he inferred that the following period would probably be seventy-six years or upwards; and consequently that the comet ought not to be expected to appear until the end of 1758, or the beginning of 1759. It is impossible to imagine any quality of mind more enviable than that which, in the existing state of mathematical physics, could have led to such a prediction. The imperfect state of science rendered it impossible for Halley to offer to the world a demonstration of the event which he foretold. "He therefore," says M. de Pontecoulant, "could only announce these felicitous conceptions of a sagacious mind as mere intuitive perceptions, which must be received as uncertain by the world, however he might have felt them himself, until they could be verified by the process of a rigorous analysis."

Subsequent researches gave increased force to Halley's prediction; for it appeared from the ancient records of observers, that comets had been seen in 1456 and 1378, whose elements were identical with those of the comet of 1682.

Fig. 26.—Feb. 7, 1836.

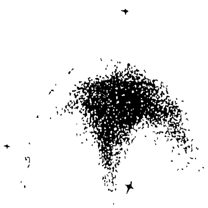


Fig. 28.—Feb. 16, 1836.

HALLEY'S COMET DEPARTING FROM THE SUN IN 1836.

COMETS.

CHAPTER III.

Halley's prediction (continued). — 55. Great advance of mathematical and physical sciences between 1682 and 1759.—56. Exact path of the comet on its return, and time of its perihelion, calculated and predicted by Clairaut and Lalande. — 57. Remarkable anticipation of the discovery of Uranus.—58. Prediction of Halley and Clairaut fulfilled by reappearance of the comet in 1758-9.—59. Disturbing action of a planet on a comet explained.—60. Effect of the perturbing action of Jupiter and Saturn on Halley's comet between 1682 and 1758.—61. Calculations of its return in 1835-36.—62. Predictions fulfilled.—63. Elements of the orbit of Halley's comet.—64. Pons's comet of 1812.—65. Olbers's comet of 1815.—66. De Vico's comet of 1846.—67. Brorsen's comet of 1847.—68. Westphal's comet of 1852.—69. Data necessary to determine the motions of these six comets.—70. Diagram of their orbits.—71. Planetary characters are nearly effaced in these orbits. —IV. Elliptic Comets, whose mean distances exceed the limits of the Solar System : 72. Synopsis of twenty-one elliptic comets of great eccentricity and long period.—73. Plan of the form and relative magnitude of the orbits.—V. 74. Hyperbolic Comets : VI. 75. Parabolic Comets.—VII. Physical constitution of Comets : 76. Apparent form—head and tail.—77.

Nucleus.—78. Coma.—79. Origin of the name.—80. Magnitude of the head.—81. Magnitude of the nucleus.—82. The tail.—83. Mass, density, and volume of comets.

THE appearance of the comet in 1456, was described by contemporary authorities to have been an object of "unheard-of magnitude;" it was accompanied by a tail of extraordinary length, which extended over sixty degrees (a third of the heavens), and continued to be seen during the whole of the month of June. The influence which was attributed to this appearance, renders it probable that in the record there exists more or less of exaggeration. It was considered as the celestial indication of the rapid success of Mohammed II., who had taken Constantinople, and struck terror into the whole Christian world. Pope Calixtus II. levelled the thunders of the Church against the enemies of his faith, terrestrial and celestial, and in the same bull exorcised the Turks and the comet; and in order that the memory of this manifestation of his power should be for ever preserved, he ordained that the bells of all the churches should be rung at midday—a custom which is preserved in those countries to our times. It must be admitted that, notwithstanding the terrors of the Church, the comet pursued its course with as much ease and security, as those with which Mohammed converted the church of St. Sophia into his principal mosque.

The extraordinary length and brilliancy which was ascribed to the tail upon this occasion, have led astronomers to investigate the circumstances under which its brightness and magnitude would be the greatest possible; and, upon tracing back the motion of the comet to the year 1456, it has been found that it was then actually under the circumstances of position with respect to the earth and sun most favourable to magnitude and splendour. So far, therefore, the results of astronomical calculation corroborate the records of history.

55. In the interval of three-quarters of a century which elapsed between the announcement of Halley's prediction and the date of its expected fulfilment, great advances were made in mathematical science; new and improved methods of investigation and calculation were invented; and, the theory of gravitation was pursued with extraordinary activity and success through its consequences in the mutual disturbances produced upon the motions of the planets and satellites, by the attraction of their masses one upon another. As the epoch of the expected return of the comet to its perihelion approached therefore, the scientific world resolved to divest, as far as possible, the prediction, of that vagueness which necessarily attended it owing to the imperfect state of science at the time it was made, and to calculate the exact effects

of those planets whose masses were sufficiently great, in accelerating or retarding its motion while passing near them.

56. This inquiry, which presented great mathematical difficulties and involved enormous arithmetical labour, was undertaken by Clairaut and Lalande: the former, a mathematician and natural philosopher, who had already applied with great success the principles of gravitation to the motions of the moon, undertook the purely analytical part of the investigation, which consisted in establishing certain general algebraical formulæ, by which the disturbing actions exerted by the planets on the comet were expressed; and Lalande, an eminent practical astronomer, undertook the labour of the arithmetical computations, in which he was assisted by a lady, Madame Lepaute, whose name has thus become celebrated in the annals of science.

When it is considered that the period of Halley's comet is about seventy-five years, and that for two successive periods, it was necessary to calculate every portion of its course separately in this way, some notion may be formed of the labour encountered by Lalande and Madame Lepaute. "During six months," says Lalande, "we calculated from morning till night, sometimes even at meals; the consequence of which was, that I contracted an illness which changed my constitution for the remainder of my life. The assistance rendered by Madame Lepaute was such, that without her we never could have dared to undertake this enormous labour, in which it was necessary to calculate the distance of each of the two planets, Jupiter and Saturn, from the comet, and their attraction upon that body, separately, for every successive degree, and for 150 years."

The name of Madame Lepaute does not appear in Clairaut's memoir; a suppression which Lalande attributes to the influence exercised by another lady to whom Clairaut was attached. Lalande, however, quotes letters of Clairaut, in which he speaks in terms of high admiration of "la savante calculatrice." The labours of this lady in the work of calculation (for she also assisted Lalande in constructing his "Ephemerides") at length so weakened her sight that she was compelled to desist. She died in 1788, while attending on her husband, who had become insane. See the article on comets, by Prof. de Morgan, in the "Companion to the British Almanac" for the year 1833.

These elaborate calculations being completed, Clairaut presented the result of their joint labours, in a memoir to the Academy of Sciences of Paris, in which he predicted the next arrival of the comet at perihelion, on the 18th of April, 1759; a date, however, which, before the re-appearance of the comet, he found reason to change to the 11th of April; and assigned the path which the

comet would follow while visible as determined by the following data :—

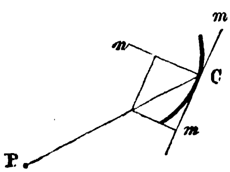
Inclination.	Longitude of node.	Longitude of perihelion.	Perihelion distance.	Direction.
17° 37′	53° 50′	303° 10′	0·58	retrograde.

57. In announcing his prediction Clairaut stated, that the time assigned for the approaching perihelion might vary from the actual time to the extent of a month ; for that independently of any error either in the methods or process of calculation, the event might deviate more or less from its predicted occurrence, by reason of the attraction of *an undiscovered planet of our system revolving beyond the orbit of Saturn.* In twenty-two years after this time this conjecture was realised, by the discovery of the planet Uranus, by the late Sir William Herschel, revolving round the sun one thousand millions of miles beyond the orbit of Saturn !

58. The comet, in fine, appeared in December 1758, and followed the path predicted by Clairaut, which differed but little from that which it had pursued on former appearances. It passed through perihelion on the 13th of March, within twenty-two days of time, and within the limit of the possible errors assigned by Clairaut.

59. The general effects of a planet in accelerating or retarding the motion of a comet are easily explained, although the exact details of the disturbances are too complicated to admit of any exposition here.

Let P, fig. 3, represent the place of the disturbing planet, and C that of the comet. The attraction of the planet on the comet will then be a force directed from C towards P, and by the principle of the composition of forces is equivalent to two components, one C *m* in the direction of the comet's path, and the other C *n* perpendicular to that path. If the motion of the comet be directed from C towards *m*, it will be accelerated ; and if it be directed from C towards *m′*, it will be retarded by that component of the planet's attraction which is directed from C to *m*. The other component C *n* being at right angles to the comet's motion, will have no direct effect either in accelerating or retarding it.

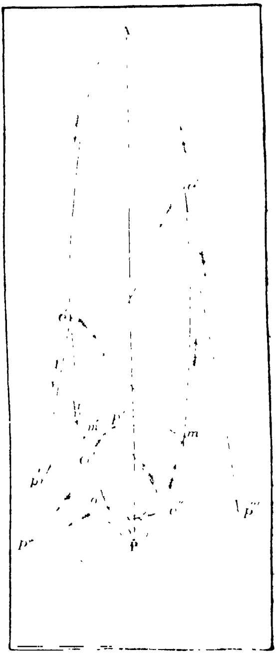


It appears, therefore, in general that, if the direction of the comet's motion C *m* make an acute angle with the line C P drawn to the planet, the planet's attraction will accelerate it ; and if

its direction C m' make an obtuse angle with the line C P, it will retard it.

This being understood, the disturbing action of a planet such as Jupiter or Saturn on a comet such as Halley's may be easily comprehended. In fig. 4, the orbit of the comet is represented at A c P c'' in its proper proportions, A P being the major axis, P the place of perihelion, A that of aphelion, and S that of the focus in which the sun is placed. The small circle described round S represents in its proper proportions the orbit of the earth, whose distance is about twice that of the comet when the latter is at perihelion. The circle p p' p'' represents in its proper proportions the orbit of Jupiter which, for illustration, we shall consider as the disturbing planet.

Fig. 4.



It will be apparent on the mere inspection of the diagram, that lines drawn from the planet whatever be its place, to any point whatever of the comet's path between its aphelion A, and the point m' where it arrives at the orbit of the planet in approaching the sun, will make acute angles with the direction of the comet's motion; and that, consequently, the comet will be accelerated by the action of the planet. In like manner, it is apparent that lines drawn from the planet whatever be its place, to any point whatever of the comet's path between m and aphelion A, will make obtuse angles with the direction of the comet's motion; and, consequently, the comet will be retarded by the action of the planet, in departing from the sun, from m to A.

In that part of the comet's path which lies within the planet's orbit, the action of the planet alternately accelerates and retards it, according to their relative position. If the planet be at p, suppose p o drawn so as to be at right angles to the path of the comet. Between m' and o the action of the planet at p will accelerate the comet, and after the comet passes o it will retard it. In like manner if the planet be at p'', it will first retard

the motion of the comet proceeding from *m′* through P towards A, and will continue to do so until the line of direction becomes perpendicular to that of the comet's motion, after which it will accelerate it.

It appears, therefore, that during the period of the comet, the disturbing action of the planet is subject to several changes of direction, owing partly to the change of position of the comet and partly to that of the planet; and the total effect of the disturbing action of the planet on the comet's period is found by taking the difference between the total amount of all the accelerating and all the retarding actions.

In the case of the planet Jupiter and Halley's comet, the former makes nearly seven complete revolutions in a single period of the comet; and consequently its disturbing action is not only subject to several changes of direction, but also to continual variation of intensity, owing to its change of distance from the comet.

Small as the arc *m′* P *m* of the comet's path is which is included within the orbit of Jupiter, the fraction of the period in which this arc is traversed by the comet is much smaller, as will be apparent by considering the application of the principle of equable areas * to this case. The time taken by the comet to move over the arc *m′* P *m* is in the same proportion to its entire period, as the area included between the arc *m′* P *m* and the lines *m′* S and *m* S is to the entire area of the ellipse A P.

To simplify the explanation the orbit of the comet has here been supposed to be in the plane of that of the disturbing planet. If it be not, the disturbing action will have another component at right angles to the plane of the comet's orbit, the effect of which will be a tendency to vary the inclination.

60. The result of the investigation by Clairaut showed, that the total effect of the disturbing action of Jupiter and Saturn on Halley's comet between its perihelions in 1682 and in 1759, was to increase its period by 618 days as compared with the time of its preceding revolution, of which increase, 100 days were due to the action of Saturn, and 518 to that of Jupiter.

Clairaut did not take into account the disturbing action of the earth, which was not altogether inconsiderable, and could not allow for those of the undiscovered planets, Uranus and Neptune. The effects of the action of the other planets, Mars, Venus, Mercury, and the planetoids, are in these cases insignificant.

61. In the interval of three quarters of a century which preceded the next re-appearance of this comet, science continued to progress, and instruments of observation and principles and

* See "Handbook of Astronomy," chap. xii. § 2599.

methods of investigation were still further improved; and, above all, the number of observers was greatly augmented. Before the epoch of its return in 1835, its motions, and the effects produced upon them by the disturbing action of the several planets, were computed by MM. Damoiseau, Pontecoulant, Rosenberger, and Lehmann, who severally predicted its arrival at perihelion:—

Damoiseau . . .	4th Nov. 1835.
Pontecoulant . . .	7th ,,
Rosenberger . . .	11th ,,
Lehmann	26th ,,

62. These predictions were all published before July, 1835. The comet was seen at Rome on the 5th August, in a position within *one degree* of the place assigned to it for that day, in the ephemeris of M. Rosenberger. On the 20th August, it became visible to all observers, and pursued the course with very little deviation, which had been assigned to it in the ephemerides, arriving at its perihelion on the 16th Nov., being very nearly a mean between the four epochs assigned in the predictions.

After this, passing south of the equator, it was not visible in northern latitudes, but continued to be seen in the southern hemisphere until the 5th of May, 1836, when it finally disappeared, not again to return until the year 1911.

63. A synoptical Table of the elements of the orbit of this comet, deduced from the observations made on each of its seven successive returns to perihelion, between 1378 and 1835 inclusive, may be seen by a reference to the "Hand-Book of Astronomy."

It appears that the mean distance of this comet is about eighteen times that of the earth, and that it is consequently at a little less than the mean distance of Uranus. When in perihelion, its distance from the sun is about half the earth's distance, while its distance in aphelion is above thirty-five times the earth's distance, and therefore seventy times its perihelion distance.

64. On the 20th of July, 1812, a comet was discovered by M. Pons, whose orbit was calculated by Professor Encké, and was found to be an ellipse of such dimensions as to give a period of $75\frac{1}{2}$ years, equal to that of Halley's comet.

65. On the 6th of March, 1815, Dr. Olbers discovered at Bremen, a comet whose orbit, calculated by Professor Bessel, proved to be an ellipse, with a period of 74 years. The next perihelion passage of this comet is predicted for the 9th of February, 1887.

66. On the 28th of February, 1846, M. de Vico discovered a comet at Rome, whose orbit, calculated by MM. van Deinse and Pierce, appears to be an ellipse, with a period of 72-73 years.

67. A comet was discovered by M. Brorsen at Altona, on the 20th of July, 1847; the orbit of which, calculated by M. d'Arrest, appears to be an ellipse, with a period of 75 years.

68. On the 27th of June, 1852, a comet was discovered by M. Westphal at Gottingen, and was soon afterwards observed by M. Peters at Constantinople. The calculation of its orbit proves it to be an ellipse, with a period of about 70 years.

69. A synoptical Table, presenting the data necessary to determine the motions of these six comets, may be seen by a reference to the "Hand-Book of Astronomy."

70. In fig. 5 (p. 145), is presented a plan of the orbits, brought upon a common plane, and drawn according to the scale indicated. This figure shows, in a manner sufficiently exact for the purposes of illustration, the relative magnitudes and the forms of the six orbits, as well as the directions of their several axes with relation to that of the first point of Aries.

71. By comparing the elements given in the table referred to above, and the forms and magnitudes of the orbits shown in the diagram, with those of the first group of elliptic comets given in Table III, "Hand-Book of Astronomy," chap. XVIII, and drawn in fig. 2 (p. 172), it will be perceived that the planetary characteristics noticed in the latter group, are nearly effaced. Five of the six comets composing the second group, revolve in the common direction of the planets, and this is the only planetary character observable among them. The inclinations, no longer limited to those of the planetary orbits, range from 18° to 74°. The eccentricities are all so extreme, that the arc of the orbit near perihelion approximates closely to the parabolic form, and the most remarkable body of the group, the comet of Halley, revolves in a direction contrary to the common motion of the planets.

But it is more than all in the elongated oval form of their orbits, that this group of comets differs, not only from the planets, but from the first group. While their perihelia are at distances from the sun, between those of Mars and Mercury, their aphelia are from two to five hundred millions of miles outside the orbit of Neptune. Thus, the comet of Halley, for example, in perihelion, is at a distance from the sun less than that of Venus; but at its aphelion, its distance exceeds that of Neptune by a space greater than Jupiter's distance from the sun. The mean angular motion of this comet is nearly the same as that of Uranus; but its angular motion in perihelion is three times that of Mercury;

while its angular motion in aphelion is little more than half that of Neptune.

The corresponding variations of solar light and heat, and of the apparent magnitude and motion of the sun as seen from the comet, may be easily inferred.

IV.—ELLIPTIC COMETS WHOSE MEAN DISTANCES EXCEED THE LIMITS OF THE SOLAR SYSTEM.

72. Although the periodicity of this class of comets has not yet in any instance been certainly established by observations made upon their successive returns to perihelion, the observations made upon them during a single perihelion passage indicate an arc of their orbit, which exhibits the elliptic form so unequivocally, as to supply computers and mathematicians with the data necessary to obtain, with more or less approximation, the value of the eccentricity, which, combined with the perihelion distance, gives the form and magnitude of the comet's orbit.

By calculations conducted in this manner, and applied to the observations made on various comets which have appeared since the latter part of the seventeenth century, the elliptic orbits of twenty-one of these bodies have been computed, and are given in the order of the dates of their perihelion passages in a table which will be found in my "Hand-Book of Astronomy."

Of this group the least eccentric is No. 15, which passed its perihelion in 1840. This comet was discovered at Berlin by M. Bremiker, and its orbit was calculated by Götze, and proved to be an ellipse, having the elements given in the table, subject to no greater uncertainty than $\frac{1}{64}$th of the value assigned to the mean distance. The eccentricity, and consequently the form of the orbit, is similar to that of Halley, but the major axis is $2\frac{2}{3}$ times, and the period nearly five times greater. Its perihelion distance is equal to that of Mars, and its aphelion distance more than three times that of Neptune.

No. 6, which passed its perihelion in 1793, has an orbit, according to the calculations of D'Arrest, nearly similar both in form and magnitude, as will be seen by comparing the numbers given in the table. More uncertainty, however, attends the estimation of these elements.

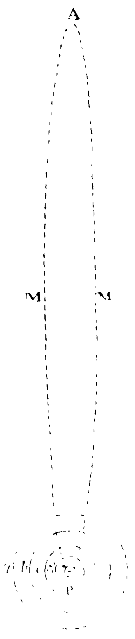
The comets which approached nearest to the sun were the great comets of 1680 and 1843, Nos. 1 and 16 in the table, both memorable for their extraordinary magnitude and splendour.

The elements of that of 1680, given in the table, are those

which have resulted from the calculations of Professor Encké, based on all the observations of the comet which have been recorded. The elements of the great comet of 1843 have resulted from the computations of Mr. Hubbard. Both are subject to considerable uncertainty, and must be accepted only as the best approximations that can be obtained.

What is not subject, however, to the same uncertainty, is the extraordinary proximity of these bodies to the sun at their respective perihelia. The perihelion distance of the comet of 1680 was about 576000 miles, and that of 1843, 538000 miles. Now the semidiameter of the sun being 441000 miles, it follows that the distance of the centres of those comets respectively from the surface of the sun at perihelion must have been only 235000 and 97000; so that if the semidiameter of the nebulous envelope of either of them exceeded this distance, they must have actually grazed the sun.

Fig. 6.



The velocity of the orbital motion of these bodies in perihelion appears by the table to be such, that the comet of 1680 would have revolved round the sun in a minute, and that of 1843 in a little less than two minutes, if they retained the same angular motion undiminished.

The distance to which the comet of 1680 recedes in its aphelion is $28\frac{1}{2}$ times greater than that of Neptune. The apparent diameter of the sun seen from that distance would be 2″, and the intensity of its light and heat would be 730000 times less than at the earth; while their intensity at the perihelion distance would be 26000 times greater, so that the light and heat received by the comet in its aphelion would be $26000 \times 730000 = 18980$ million times less than in perihelion.

The greatest aphelion distances in the table are those of Nos. 5, 13, and 17, the comets of 1780, 1830, and 1844, amounting to from 100 to 140 times the distance of Neptune; the eccentricities differing from unity by less than $\frac{1}{1000}$. These orbits, though strictly the results of calculation, must be regarded as subject to considerable uncertainty.

73. To convey an idea of the form of the orbits of the comets of this group, and of the proportion which their magnitude bears to the dimensions of the solar system, we have drawn in

fig. 6, an ellipse, which may be considered as representing the form of the orbits of the comets Nos. 15, 6, 9, 12, and 1, of Table VI in the "Handbook of Astronomy."

If the ellipse represent the orbit of the comet No. 15, the circle *a* will represent on the same scale the orbit of Neptune.

If the ellipse represent the orbit of the comet No. 6, the circle *b* will represent the orbit of Neptune.

If the ellipse represent the orbit of No. 9, the circle *c* will represent the orbit of Neptune.

If the ellipse represent the orbit of No. 12, the circle *d* will represent the orbit of Neptune.

If the ellipse represent the orbit of No. 1, the circle *e* will represent the orbit of Neptune.

V.—HYPERBOLIC COMETS.

74. In a Table in the "Hand-Book of Astronomy" are given the elements of seven comets which appear by the results of calculations made upon the observations to have passed through the system in hyperbolic orbits.

VI.—PARABOLIC COMETS.

75. Of all the remaining number of comets which have been seen in the heavens and recorded in history, one hundred and sixty-one have been observed with sufficient precision to enable astronomers to determine, with more or less approximation, their parabolic orbits. A table giving the elements of these, with the dates of their appearance, will be found in the eighteenth chapter of the "Handbook of Astronomy."

VII.—PHYSICAL CONSTITUTION OF COMETS.

76. Comets in general, and more especially those which are visible without a telescope, present the appearance of a roundish mass of illuminated vapour or nebulous matter, to which is often, though not always, attached a train more or less extensive, composed of matter having a like appearance. The former is called the HEAD, and the latter the TAIL, of the comet.

77. The illumination of the head is not generally uniform. Sometimes a bright central spot is seen in the nebulous matter which forms it. This is called the NUCLEUS.

The nucleus sometimes appears as a bright stellar point, and

sometimes presents the appearance of a planetary disc seen through a nebulous haze. In general, however, on examining the object with high optical power, these appearances are changed, and the object seems to be a mere mass of illuminated vapour from its borders to its centre.

78. When a nucleus is apparent, or supposed to be so, the nebulous haze which surrounds it and forms the exterior part of the head is called the *coma*.

79. These designations are taken from the Greek word *κομή* (komē) hair, the nebulous matter composing the coma and tail being supposed to resemble hair, and the object being therefore called *κομήτης* (kometes), a hairy star.

80. As the brightness of the coma gradually fades away towards the edges, it is impossible to determine with any great degree of precision its real dimensions. These, however, are obviously subject to enormous variation, not only in different comets compared one with another, but even in the same comet during the interval of a single perihelion passage. The greatest of those which have been submitted to micrometrical measurement was the great comet of 1811, the diameter of the head of which was found to be not less than $1\frac{1}{8}$ millions of miles, which would give a volume greater than that of the sun in the ratio of about 2 to 1. The diameter of the head of Halley's comet when departing from the sun, in 1836, at one time measured 357000 miles, giving a volume more than sixty times that of Jupiter. These are, however, the greatest dimensions which have been observed in this class of objects, the diameter rarely exceeding 200000 miles, and being generally less than 100000.

81. Attempts have been made where nuclei were perceivable, to estimate their magnitude, and diameters have been assigned to them, varying from 100 to 5000 miles. For the reasons, however, already explained, these results must be regarded as very doubtful.

Those who deny the existence of solid matter within the coma, maintain that even the most brilliant and conspicuous of those bodies, and those which have presented the strongest resemblance to planets, are more or less transparent. It might be supposed that a fact so simple as this, in this age of astronomical activity, could not remain doubtful; but it must be considered, that the combination of circumstances which alone would test such a question, is of rare occurrence. It would be necessary that the centre of the head of the comet, although very small, should pass critically over a star, in order to ascertain whether such star is visible through it. With comets having extensive comæ without nuclei, this has sometimes occurred; but we have not had such

satisfactory examples in the more rare instances of those which have distinct nuclei.

In the absence of a more decisive test of the occultation of a star by the nucleus, it has been maintained that the existence of a solid nucleus may be fairly inferred from the great splendour which has attended the appearance of some comets. A mere mass of vapour could not, it is contended, reflect such brilliant light. The following are the examples adduced by Arago:—

"In the year 43 before Christ, a comet appeared which was said to be visible to the naked eye by daylight. It was the comet which the Romans considered to be the soul of Cæsar transferred to the heavens after his assassination.

"In the year 1402 two remarkable comets were recorded. The first was so brilliant that the light of the sun at noon, at the end of March, did not prevent its nucleus, or even its tail, from being seen. The second appeared in the month of June, and was visible also for a considerable time before sunset.

"In the year 1532, the people of Milan were alarmed by the appearance of a star which was visible in the broad daylight. At that time Venus was not in a position to be visible, and consequently it is inferred that this star must have been a comet.

"The comet of 1577 was discovered on the 13th of November by Tycho Brahe, from his observatory on the isle of Huene, in the Sound, before sunset.

"On the 1st of February, 1744, Chizeaux observed a comet more brilliant than the brightest star in the heavens, which soon became equal in splendour to Jupiter, and in the beginning of March it was visible in the presence of the sun. By selecting a proper position for observation, on the 1st of March it was seen at one o'clock in the afternoon without a telescope."

Such is the amount of evidence which observation has supplied respecting the existence of a solid nucleus. The most that can be said of it is, that it presents a plausible argument, giving some probability, but no positive certainty, that comets have visited our system which have solid nuclei, but, meanwhile, this can only be maintained with respect to a few: most of those which have been seen, and all to which very accurate observations have been directed, have afforded evidence of being mere masses of semi-transparent matter.

82. Although by far the great majority of comets are not attended by tails, yet that appendage, in the popular mind, is more inseparable from the idea of a comet than any other attribute of these bodies. This proceeds from its singular and striking appearance, and from the fact that most comets visible to the naked eye have had tails. In the year 1531, on the occasion of

one of the visits of Halley's comet to the solar system, Pierre Apian observed that the comet generally presented its tail in the direction opposite to that of the sun. This principle was hastily generalised, and is even at present too generally adopted. It is true that in most cases the tail extends itself from that part of the comet which is most remote from the sun; but its direction rarely corresponds with the direction which the shadow of the comet would take. Sometimes it has happened that the tail forms with a line drawn to the sun a considerable angle, and cases have occurred when it was actually at right angles to it.

Another character which has been observed to attach to the tails of comets, which, however, is not invariable, is, that they incline constantly toward the region last quitted by the comet, as if in its progress through space it were subject to the action of some resisting medium, so that the nebulous matter with which it is invested, suffering more resistance than the solid nucleus, remains behind it and forms the tail.

The tail sometimes appears to have a curved form. That of the comet of 1744 formed almost a quadrant. It is supposed that the convexity of the curve, if it exists, is turned in the direction from which the comet moves. It is proper to state, however, that these circumstances regarding the tail have not been clearly and satisfactorily ascertained.

The tails of comets are not of uniform breadth or diameter; they appear to diverge from the comet, enlarging in breadth and diminishing in brightness as their distance from the comet increases. The middle of the tail usually presents a dark stripe, which divides it longitudinally into two distinct parts. It was long supposed that this dark stripe was the shadow of the body of the comet, and this explanation might be accepted if the tail was always turned from the sun; but we find the dark stripe equally exists when the tail, being turned sideways, is exposed to the effect of the sun's light.

This appearance is usually explained by the supposition that the tail is a hollow, conical shell of vapour, the external surface of which possesses a certain thickness. When we view it, we look through a considerable thickness of vapour at the edges, and through a comparatively small quantity at the middle. Thus upon the supposition of a hollow cone, the greatest brightness would appear at the sides, and the existence of a dark space in the middle would be perfectly accounted for.

The tails of comets are not always single; some have appeared at different times with several separate tails. The comet of 1744, which appeared on the 7th or 8th of March, had six tails, each about 4° in breadth, and from 30° to 44° in length. Their

sides were well defined and tolerably bright, and the spaces between them were as dark as the other parts of the heavens.

The tails of comets have frequently appeared, not only of immense real length, but extending over considerable spaces of the heavens. It will be easily understood that the apparent length depends conjointly upon the real length of the tail, and the position in which it is presented to the eye. If the line of vision be at right angles to it, its length will appear as great as it can do at its existing distance; if it be oblique to the eye, it will be foreshortened, more or less, according to the angle of obliquity. The real length of the tail is easily calculated when the apparent length is observed and the angle of obliquity known.

In respect of magnitude, the tails are unquestionably the most stupendous objects which the discoveries of the astronomer have ever presented to human contemplation.

The following are the results of the observation and measurement of a few of the more remarkable.

Table.	No.	Date of Appearance.	Greatest observed Length of Tail.
			miles.
VIII	148	1847	5000000
—	73	1744	19000000
VI	4	1769	40000000
VIII	46	1618	50000000
VI	1	1680	100000000
—	8	1811	100000000
—	9	1811	130000000
—	16	1843	200000000

The magnitude of these prodigious appendages is even less amazing than the brief period in which they sometime emanate from the head. The tail of the comet of 1843, long enough to stretch from the sun to the planetoids, was formed in less than twenty days.

83. The masses of comets, like those of the planets, would be ascertained if the reciprocal effects of their gravitation and those of any known bodies in the system could be observed. But although the disturbing action of the planets on these bodies is conspicuous, and its effects have been calculated and observed, not the slightest effect of the same kind has ever been ascertained to be produced by them, even upon the smallest bodies in the system, and those to which comets have approached most nearly.

In fine, notwithstanding the enormous number of comets,

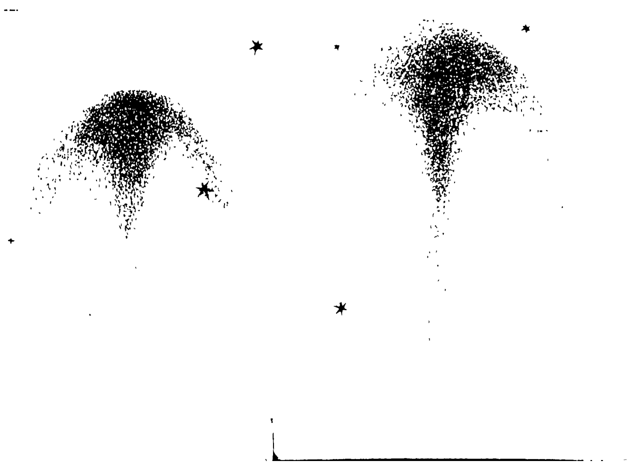
observed and unobserved, which constantly traverse the solar system in all conceivable directions; notwithstanding the permanent revolution of the periodic comets, whose presence and orbits have been ascertained; notwithstanding the frequent visits of comets, which so thoroughly penetrate the system as almost to touch the surface of the sun at their perihelion, the motions of the various bodies of the system, great and small, planets major and minor, planetoids and satellites, go on precisely as if no such bodies as the comets approached their neighbourhood. Not the smallest effects of the attraction of such visitors are discoverable.

Now since, on the other hand, the disturbing effects of the planets upon the comets are strikingly manifest, and since the comets move in elliptic, parabolic, or hyperbolic orbits, of which the sun is the common focus, it is demonstrated that these bodies are composed of ponderable matter, which is subject to all the consequences of the law of gravitation. It cannot, therefore, be doubted that the comets do produce a disturbing action on the planets, although its effects are inappreciable even by the most exact observation. Since, then, the disturbances mutually produced are in the proportion of the disturbing masses, it follows that the masses of the comets must be smaller beyond all calculation than the masses even of the smallest bodies among the planets primary or secondary.

The volumes of comets in general exceed those of the planets in a proportion nearly as great as that by which the masses of the planets exceed those of the comets. The consequence obviously resulting from this, is that the density of comets is incalculably small.

Their densities in general are probably thousands of times less than that of the atmosphere in the stratum next the surface of the Earth.

Fig. 27.—February 10, 1836. Fig. 29.—February 23, 1836.



HALLEY'S COMET DEPARTING FROM THE SUN IN 1836.

COMETS.

CHAPTER IV.

84. Light of comets.—85. Enlargement of magnitude on departing from the sun.—86. Professor Struve's drawings of Encke's comet.—87. Remarkable physical phenomena manifested by Halley's comet.—88. Struve's drawings of the comet approaching the sun in 1835.—89. Its appearance on the 29th of Sept.—90. Appearance on Oct. 3.—91. Appearance on Oct. 6.—92. Appearance on Oct. 9.—93. Appearance on Oct. 10.—94. Appearance on Oct. 12.—95. Appearance on Oct. 14.—96. Appearance on Oct. 29.—97. Appearance on Nov. 5.—98. Sir J. Herschel's deductions from these phenomena.—99. Appearance of the comet after perihelion.—100. Observations and drawings of MM. Maclear and Smith.—101. Appearance on Jan. 24.—102. Appearance on Jan. 25.—103. Appearance on Jan. 26.—104. Appearance on Jan. 27.—105. Appearance on Jan. 28.—106. Appearance on Jan. 30.—107. Appearance on Feb. 1.—108. Appearance on Feb. 7.—109. Appearance on Feb. 10.—110. Appearance on Feb. 16 and 23.—111. Number of comets.—112. Duration of the appearance of comets.—113. Near approach of comets to the earth.

84. THAT planets are not self-luminous, but receive their light from the sun, is proved by their phases, and by the shadows of

their satellites, which are projected upon them, when the latter are interposed between them and the sun. These tests are inapplicable to comets. They exhibit no phases, and are attended by no bodies to intercept the sun's light. But, unless it could be shown that a comet is a solid mass, impenetrable to the solar rays, the non-existence of phases is not a proof that the body does not receive its light from the sun.

A mere mass of cloud or vapour, though not self-luminous, but rendered visible by borrowed light, would still exhibit no effect of this kind: its imperfect opacity would allow the solar light to affect its constituent parts throughout its entire depth—so that, like a thin fleecy cloud, it would appear not superficially illuminated, but receiving and reflecting light through all its dimensions. With respect to comets, therefore, the doubt which has existed is, whether the light which proceeds from them, and by which they become visible, is a light of their own, or is the light of the sun shining upon them, and reflected to our eyes like light from a cloud. Among several tests which have been proposed to decide this question, one suggested by Arago merits attention.

It has been already shown in our Tract on "the Eye" (43), that the apparent brightness of a visible object is the same at all distances, supposing its real brightness to remain unchanged. Now if comets shone with their proper light, and not by light received from the sun, their apparent brightness would not decrease as they would recede from the sun, and they would cease to be visible, not because of the faintness of their light, but because of the smallness of their apparent magnitude. Now the contrary is found to be the case. As the comet retires from the sun its apparent brightness rapidly decreases, and it ceases to be visible from the mere faintness of its light, while it still subtends a considerable visual angle.

85. It will doubtless excite surprise, that the dimensions of a comet should be enlarged as it recedes from the source of heat. It has been often observed in astronomical inquiries, that the effects, which at first view seem most improbable, are nevertheless those which frequently prove to be true; and so it is in this case. It was long believed that comets enlarged as they approached the sun; and this supposed effect was naturally and probably ascribed to the heat of the sun expanding their dimensions. But more recent and exact observations have shown the very reverse to be the fact. Comets increase their apparent volume as they recede from the sun; and this is a law to which there appears to be no well-ascertained exception. This singular and unexpected phenomenon has been attempted to be accounted

for in several ways. Valz ascribed it to the pressure of the solar atmosphere acting upon the comet; that atmosphere being more dense near the sun, compresses the comet and diminishes its dimensions; and, at a greater distance, being relieved from this coercion, the body swells to its natural bulk. A very ingenious train of reasoning was produced in support of this theory. The density of the solar atmosphere and the elasticity of the comet, being assumed to be such as they might naturally be supposed, the variations of the comet's bulk are deduced by strict reasoning, and show a surprising coincidence with the observed change in the dimensions. But this hypothesis is tainted by a fatal error. It proceeds upon the supposition that the comet, on the one hand, is formed of an elastic gas or vapour; and, on the other, that it is impervious to the solar atmosphere through which it moves. To establish the theory, it would be necessary to suppose that the elastic fluid composing the comet should be surrounded by a *nappe* or envelope as elastic as the fluid composing the comet, and yet wholly impenetrable by the solar atmosphere.

Several ingenious hypotheses * have been proposed and successively rejected for explaining this phenomenon, but it seems now agreed to ascribe it to the action of the varying temperature to which the vapour which composes the nebulous envelope is exposed. As the comet approaches the sun, this vapour is converted by intense heat into a pure, transparent, and therefore invisible elastic fluid. As it recedes from the sun, the temperature decreasing, it is partially and gradually condensed, and assumes the form of a semitransparent visible cloud, as steam does escaping from the valve of a steam boiler. It becomes more and more voluminous as the distance from the source of heat, and therefore the extent of condensation, is augmented.

86. Professor Struve made a series of observations on the comet of Encké, at the period of its reappearance in 1828, and by the aid of the great Dorpat telescope, made the drawings figs. 7 and 8.

Fig. 7 represents the comet as it appeared on the 7th November, the diameter *a b* measuring 18′. The brightest part of the comet extended from *k* to *l*, and was consequently eccentric to it, the distance of the centre of brightness from the centre of magnitude being *k* K. Between the 7th and the 30th November, the magnitude of the comet decreased from that represented in fig. 7, to that represented in fig. 8; but the

* For several of these, see Sir J. Herschel's memoir, "Proceedings of Astronomical Society," vol. vi. p. 104.

apparent brightness was so much increased, that at the latter date it was visible to the naked eye as a star of the 6th magnitude. The apparent diameter was then reduced to 9′.

On November 7th a star of the 11th magnitude was seen through the comet, so near the centre of brightness that it was for a moment mistaken for a nucleus. The brightness of the star was not in the least perceptible degree dimmed by the mass of cometary matter through which its light passed.

It was evident that the increase of the brightness of the comet on the 30th November, must be ascribed to the contraction, and consequent condensation, of the nebulous matter composing it in receding from the sun, for its distance from the earth on the 7th November, when it subtended an angle of 18′, was 0·515 (the earth's mean distance from the sun being =1); while its distance on the 30th, when it subtended an angle of 9′, was only 0·477. Its cubical dimensions must, therefore, have been diminished, and the density of the matter composing it augmented in more than eight-fold proportion.

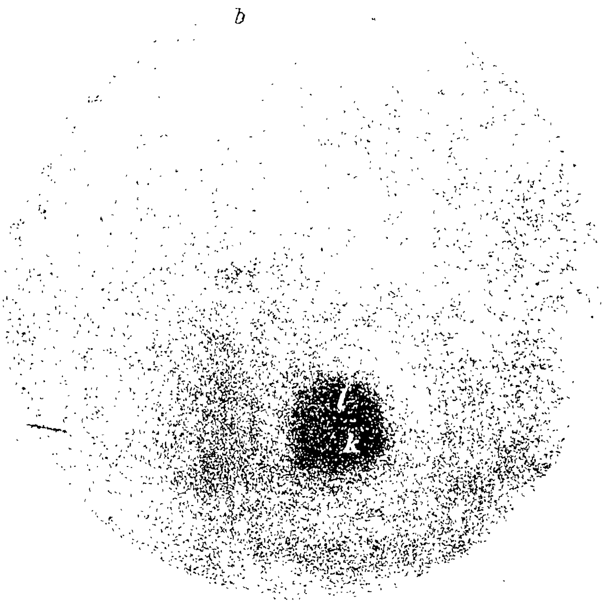
87. The expectation so generally entertained, that, on the occasion of its return to perihelion in 1835, this comet would afford observers occasion for obtaining new data, for the foundation of some satisfactory views respecting the physical constitution of the class of which it is so striking an example, was not disappointed. It no sooner reappeared than phenomena began to be manifested, preceding and accompanying the gradual formation of the tail, the observation of which has been most justly regarded as forming a memorable epoch in astronomical history.

Happily, these strange and important appearances were observed with the greatest zeal, and delineated with the most elaborate and scrupulous fidelity by several eminent astronomers in both hemispheres. MM. Bessel at Konigsburg, Schwabe at Dessau, and Struve at Pultowa, and Sir J. Herschel and Mr. Maclear at the Cape of Good Hope, have severally published their observations, accompanied by numerous drawings, exhibiting the successive transformations presented under the physical influence of varying temperature, in its approach to and departure from the sun.

The comet first became visible as a small round nebula, without a tail, and having a bright point more intensely luminous than the rest eccentrically placed within it. On the 2nd October, the tail began to be formed, and, increasing rapidly, acquired a length of about 5° on the 5th; on the 20th it attained its greatest length, which was 20°. It began after that day to decrease, and its diminution was so rapid, that on the 29th it was reduced to 3°,

ENCKE'S COMET.

Fig. 7.—Encke's Comet, 1828, approaching the Sun; as it appeared 7th Nov., 1828. (Telescopic drawing by Struve.)



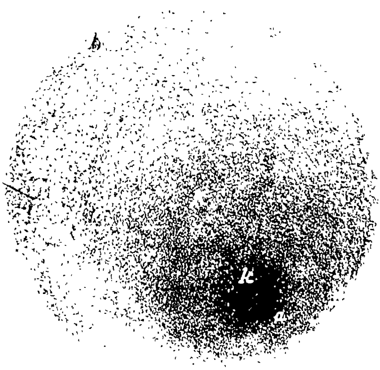


Fig. 8.—The same as it appeared 30th November, 1828.

and on the 5th of November, to 2½°. The comet was observed on the day of its perihelion by M. Struve, at the Observatory of Pultowa, when no tail whatever was apparent.

The circumstances which accompanied the increase of the tail from 2nd October, until its disappearance, were extremely remarkable, and were observed with scrupulous precision, simultaneously by Bessel at Konigsburg, by Struve at Pultowa, and by Schwabe at Dessau, all of whom made drawings from time to time, delineating the successive changes which it underwent.

On the 2nd, the commencement of the formation of the tail took place, by the appearance of a violent ejection of nebulous matter from that part of the comet which was presented towards the sun. This ejection was, however, neither uniform nor continuous. Like the fiery matter issuing from the crater of a volcano, it was thrown out at intervals. After the ejection, which was conspicuous, according to Bessel, on the 2nd, it ceased, and no efflux was observed for several days. About the 8th, however, it recommenced more violently than before, and assumed a new form. At this time Schwabe noticed an appearance which he denominates a "second tail," presented in a direction opposed to that of the original tail, and, therefore, towards the sun. This appearance seems, however, to be regarded by Bessel merely as the renewed ejection of nebulous matter which was afterwards turned back from the sun, as smoke would be by a current of air blowing from the sun in the direction of the original tail.

Fig. 9.—Sept. 29, 1835.

From the 8th to the 22nd, the form, position, and brightness of the nebulous emanations underwent various and irregular changes, the last alternately increasing and decreasing.

At one time two, at another three, nebulous emanations were observed to issue in divergent directions. These directions were continually varying, as well as their comparative brightness. Sometimes they would assume a swallow-tailed form, resembling the flame issuing from a fan gas-burner. The principal jet or tail was also observed to oscillate on the one side and the other of a line drawn from the sun through the centre

of the head of the comet, exactly as a compass needle oscillates between the one and the other side of the magnetic meridian. This oscillation was so rapid, that the direction of the jets was visibly changed from hour to hour. The brightness of the matter composing them, being most intense at the point at which it seemed to be ejected from the nucleus, faded away as it expanded into the coma, curving backwards, in the direction of the principal tail, like steam or smoke before the wind.

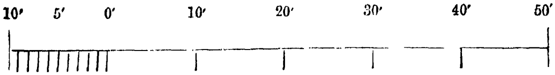
Fig. 10.—Oct. 3, 1835.

88. These curious phenomena will, however, be more clearly conceived by the aid of the admirable drawings of M. Struve, which we have reproduced with all practicable fidelity, in figs. 9, 10, 11, 12, 13, 14, 15, 16, 17, and 18. These drawings were executed by M. Kruger, an eminent artist, from the immediate observation of the appearances of the comet with the great Fraunhoffer telescope, at the Pultowa Observatory. The sketches of the artist were corrected by the astronomer, and only adopted definitively after repeated comparisons with the object. The original drawings are preserved in the library of the observatory.

89. Fig. 9 (page 198) represents the appearance of the comet on the 29th September. The tail was difficult to be recognised, appearing to be composed of very feeble nebulous matter. The nucleus passed

almost centrically over a star of the tenth magnitude, without in the slightest degree affecting its apparent brightness. The star was distinctly seen through the densest part of the comet. Another transit of a star took place with a like result.

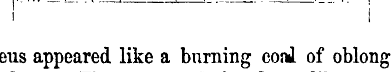
Annexed is the scale according to which this drawing has been made.



90. The comet changed not only its magnitude and form, but also its position, after September 29. On that day the direction of the tail was that of the parallel of declination through the head. On October 3rd it was inclined from that parallel towards the north at a small angle, and, instead of being straight, was curved, as shown in fig. 10 (page 199). The diameter of the head was increased in the ratio of 2 to 3, and the length of the tail in the ratio of nearly 1 to 3.

Fig. 11.—Oct. 8, 1835.

91. On the 5th, 6th, and 7th the comet underwent several changes: the nucleus became more conspicuous. On the 6th, a fan-formed flame issued from it, which disappeared on the 7th, and re-appeared on the 8th with increased splendour, as represented in fig. 11, which is drawn on the subjoined scale:



The nucleus appeared like a burning coal of oblong form, and yellowish colour. The extent of the flame-like emanation was about 30″. The feeble nebula surrounding the nuclei extended much beyond the limits of the drawing, but, being overpowered by the moonlight, could not be measured.

92. The comet as it appeared on the following night is shown in fig. 12, which is on the same scale as fig. 11. The nucleus and flame-like emanation entirely changed their form and magnitude

since the preceding night. The tail (not included in the drawing) measured very nearly 2°. The flame consisted of two parts, one resembling that seen on the 8th, and the other issuing like the jet from a blow-pipe in a direction at right angles to it. The figure represents the nucleus and flame as they appeared at 21ʰ sidereal time, with a magnifying power of 254.

Fig. 12.—Oct. 9, 1835.

93. The appearance of the following night is shown on the same scale in fig. 13. The tail, which still measured nearly 2°, was now much brighter, being visible to the naked eye, notwithstanding strong moonlight. The coma was evidently broader than the tail. The flaming nucleus is represented in the drawing as it appeared under a magnifying power of 86, with a field of 18′ diameter, the entire of which was filled with this coma. The diameter of the latter must, therefore, have been more than 18′. The drawing was taken at 21ʰ. s. t.

Fig. 13.—Oct. 10, 1835.

94. The comet is represented in fig. 14 (page 202), on the same scale, as it appeared on the night of the 12th. It appeared at 0ʰ 25ᵐ s. t. for a short interval in uncommon splendour, the nucleus and flame, however, alone being visible, as represented in the drawing. The greatest extent of the flame measured 64″·7. Its appearance was most beautiful,

resembling a jet streaming out from the nucleus, like flame from a blow-pipe, or the flame from the discharge of a mortar, attended

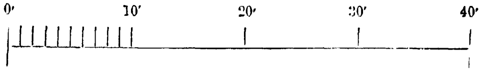
Fig. 14.—Oct. 12, 1835.

Fig. 15.—Oct. 14, 1835.

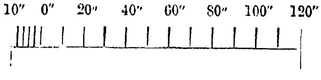
with the white smoke driven before the wind.

95. Its appearance on the 14th is shown, on the same scale, in fig. 15. The principal flame was now greatly enlarged, extending to the apparent length of 134″. Its deflection and curved form were most remarkable.

96. A cloudy sky prevented all observation for 12 days. On the 27th, the comet appeared to the naked eye as bright as a star of the third magnitude, the tail being distinctly visible. The coma surrounding the nucleus appeared as a uniform nebula. The tail was curved and of great length; but, owing to the low altitude at which the observation was taken, it could not be measured. On the 29th, however, the comet was presented under much more favourable conditions, and the drawings, fig. 16 and fig. 17 were made. The former represents the entire comet, including the whole visible extent of the tail, and is drawn to the annexed scale of minutes.



The latter represents the head of the comet only, and is drawn to the annexed scale of seconds.

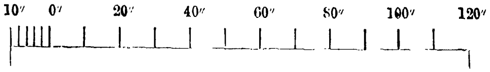


At $20^h\ 30^m$ s. t., the head presented the appearance represented in fig. 17 (page 204). The chief coma was almost exactly circular, and had a diameter of 165″. With a power of 198, the nucleus appeared as in the figure, the diameter being about 1″·25 to 1″·50. The flame issuing from the nucleus, curved back like smoke before the wind, was very conspicuous. The appearance of the formation of the tail as it issues from the nucleus was remarkably developed.

Fig. 16.—Oct. 29, 1835.

97. On the 5th of November the comet appeared as shown in fig. 18 (page 204). This drawing represents the nucleus and flame issuing from it on the scale of seconds given below.

The proper nucleus was found to measure about 2″·3. Two flames were seen issuing from it in nearly opposite directions, and both curved towards the same side. The brighter flame, directed towards the north, was marked by strongly defined edges. The other, directed towards the south, was more feeble and ill-defined.



98. Sir J. Herschel, who also observed this comet himself at the Cape of Good Hope, makes from all these observations the following inferences.

(1.) That the matter of the comet vaporised by the sun's heat escapes in jets, throwing the comet into irregular motion by its reaction, and thus changing its own direction of ejection.

(2.) That this ejection takes place principally from the part presented to the sun.

(3.) That thus ejected it encounters a resistance from some

Fig. 17.—Oct. 29, 1835.

Fig. 18.—Nov. 5, 1835.

unknown force by which it is repulsed in the opposite direction, and so forms the tail.

(4.) That this acts unequally on the cometary matter, which is not all vaporised, and of that which is, a considerable portion is retained, so as to form the head and coma.

(5.) That this force cannot be solar gravitation, being contrary to that in its direction, and very much greater in its intensity, as is manifest by the enormous velocity with which the matter of the tail is driven from the sun.

(6.) That the matter thus repelled to a distance so great from a body whose mass is so small must, to a great extent, escape from the feeble influence of the gravitation of the mass composing the head and coma, and, unless there be some more active agency in operation, a large portion of such vaporised matter must be lost in space, never to reunite with the comet. This would lead to the consequence, that at every passage through its perihelion the comet would lose more and more of its vaporisable constituents, on which the production of the coma and tail depends, so that, at each successive return, the dimensions of these appendages would be less and less, as they have in fact been found to be.

99. On receding from the sun after its perihelion, the comet was observed under very favourable circumstances at the Cape by Sir J. Herschel and Mr. Maclear. It first reappeared there on the 24th of January, under an aspect altogether different from that under which it was seen before its perihelion. It had evidently, as Sir J. Herschel thinks, undergone some great physical change, which had operated an entire transformation upon it.

"Nothing could be more surprising than the total change which had taken place in it since October. . . . A new and unexpected phenomenon had developed itself, quite unique in the history of comets. Within the well-defined head, somewhat eccentrically placed, was a vivid nucleus resembling a miniature comet, with a head and tail of its own, perfectly distinct from and considerably exceeding in intensity the nebulous disc or envelope which I have above called the 'head.' A minute bright point, like a small star, was distinctly perceived within it, but which was never quite so well defined as to give the positive assurance of the existence of a solid sphere, much less could any phase be discerned." *

100. The phenomena and changes which the comet presented from its reappearance on the 24th of January, until its final

* "Cape Observations," p. 397.

disappearance, have been described with great clearness by Mr. Maclear, and illustrated by a beautiful series of drawings by that astronomer and his assistant, Mr. Smith, in a memoir which appeared in the tenth volume of the Transactions of the Royal Astronomical Society, from which we reproduce the series of illustrations given in fig. 19 to fig. 29.

101. On the night of the 24th of January, 1836, the comet appeared, as in fig. 19, visible to the naked eye as a star of the second magnitude. The head was nearly circular, and presented a pretty well-defined planetary disc, encompassed by a coma or halo of delicate gossamer-like brightness. The diameter of the head, without the halo or coma, measured 131″, and with the latter 492″.

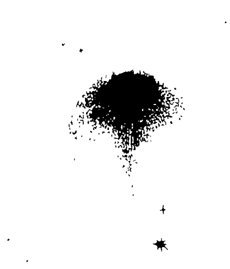
102. On the night of the 25th the comet had the appearance represented in fig. 20. The circular form was broken, and the magnitude of the head was increased. Three stars were seen through the coma and one through the head.

103. On the 26th of January the magnitude of the head was further increased, but that of the coma was diminished (fig. 21).

104. On the 27th the comet began to assume a parabolic form, as shown in fig. 22, and the increasing magnitude continued.

105. On the 28th the coma or halo was quite invisible, but the nucleus appeared like a faint small star. The magnitude of the comet continued to increase. The observer fancied he saw the faint outline of a tail (fig. 23).

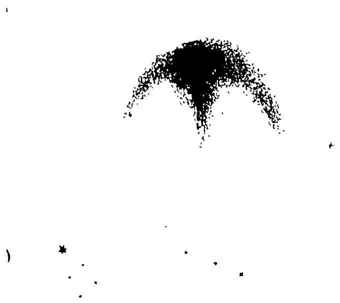
Fig. 23.—January 28, 1836.



106. On the 30th the form of the comet became decidedly parabolic (fig. 24). The breadth across the head was 702″, being greater than on the 24th in the ratio of 49 to 70, or 7 to 10,

which corresponds to an increase of volume in the ratio of 1 to 3, supposing the form to remain unchanged; but it was estimated

Fig. 24.—January 30, 1836.



that the extension in length gave a superficial increase in the ratio of 35 to 1, which would correspond to a much greater augmentation of volume.

107. On the 1st of February a further increase of magnitude took place, the figure remaining the same (fig. 25).

Fig. 25.—February 1, 1836.

108. On the 7th of February the comet was rendered faint by the effect of moonlight (fig. 26).

109. On the 10th a further increase of volume took place, a star being visible through the body (fig. 27).

110. From the 16th, on which it presented the appearance shown in fig. 28, to the 23rd, when it assumed the appearance shown in fig. 29, the magnitude went on increasing, while the illumination became more and more faint, and this continued until the comet's final disappearance; the outline, after a short time, became so faint as to be lost in the surrounding darkness, leaving a bland nebulous blotch with a bright centre enveloping the nucleus.

111. According to Mr. Hind, the number of comets which have appeared since the birth of Christ in each successive century is as follows: first century, 22; second, 23; third, 44; fourth, 27; fifth, 16; sixth, 25; seventh, 22; eighth, 16; ninth, 42; tenth, 26; eleventh, 36; twelfth, 26; thirteenth, 26; fourteenth, 29; fifteenth, 27; sixteenth, 31; seventeenth, 25; eighteenth, 64; nineteenth (first half), 80. Total, 607.

112. Since comets are visible only near their perihelia, when their velocity is greatest, the duration of their visibility at any single perihelion passage is generally short. The longest appearance on record is that of the great comet of 1811 (No. 8, Table VI., "Hand-Book of Astronomy," chap. xviii.), which continued to be visible for 510 days. The comet of 1825 (No. 2, Table VI. "Hand-Book of Astronomy," chap. xviii.) was visible for twelve months, and others which appeared since have been seen for eight months. In general, however, these bodies do not continue to be seen for more than two or three months.

113. Considering the vast number of comets which have passed through the system, such an incident as the collision of one of them with a planet might seem no very improbable contingency. Lexell's comet was supposed to have passed among the satellites of Jupiter; and, if that was the case, it is certain that the motions of these bodies were not in the least affected by it. The nearest approach to the earth ever made by a comet was that of the comet of 1684 (No. 55, Table VIII., "Hand-Book of Astronomy," chap. xviii.), which came within 216 semidiameters of the earth, a distance not so much as four times that of the moon. We are not aware of any nearer approach than this being certainly ascertained.

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THE PRE-ADAMITE EARTH.

ECLIPSES.

SOUND.

The numbers of the paragraphs and figures of the "PRE-ADAMITE EARTH," *are continuous with those of the* "CRUST OF THE EARTH," *in volume* XI., *of which subject the* "PRE-ADAMITE EARTH" *is the continuation and development. This statement will explain what might otherwise seem incorrect in the numbering of the paragraphs and figures.*

ERRATA.

Pre-Adamite Earth, page 85, paragraph 362, line 2, *for* "160," *read* "163."
" " page 86, line 10, *for* "Equitaceæ," *read* "Equisetaceæ."

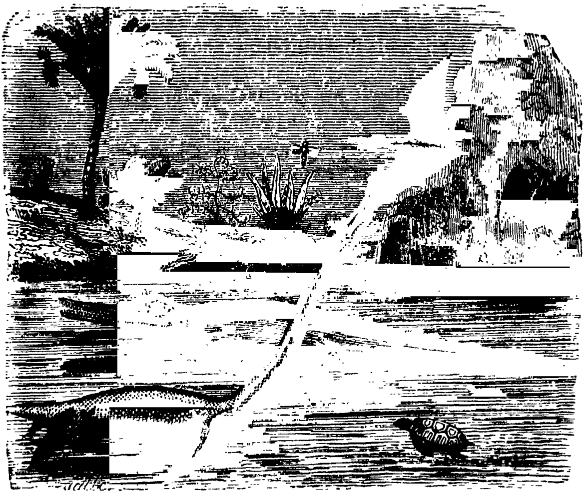


Fig. 161.—ILLUSTRATION OF THE ANIMAL AND VEGETABLE KINGDOMS DURING THE JURASSIC AGE.

THE PRE-ADAMITE EARTH.

CHAPTER I.

186. Interest of the subject.—187. Recapitulation.—188. Original division of the land and water.—189. Uniform temperature at all latitudes.—190. This temperature at first too elevated for organic life.—191. Its gradual reduction.—192. Series of convulsions.—193. Depositions of organic remains.—194. First organic creation after the fourth convulsion.—195. The latest catastrophe of this kind.—196. Method of determining the age of mountains.—197. Ranges of similar date parallel.—198. Their nomenclature.—199. Method of ascertaining the outlines of land and water at each geological epoch.—200. M. Elie de Beaumont's seventeen mountain systems.—201. Their directions and denominations.—202. Manner in which they are grouped.—203. Plan of these systems in Europe.—204. Their geological dates.—205. System of Vendée.—206. System of Finistère.—207. System of Longmynd.—208. System of Morbihan.—209. System of Hundsruck.—210. System of the Ballons.—211. System of the North of England.—212. System of Hainault.—213. System of the Rhine.—214. System of Thuringerwald.

186. The history of our planet before it was clothed with that variety of vegetation which now adorns it, and became the

habitation of man and the contemporaneous tribes of animals, cannot fail to be a subject of interest the most exciting and profound. In our Tract on the "Crust of the Earth," some glimpses of this pre-Adamite chronology were disclosed. We purpose at present to resume the subject with more system and detail, assuming that our readers have already rendered themselves familiar with the facts, phenomena, and principles which were there stated and explained.

187. Before we enter upon this curious narrative, however, it will be useful to recapitulate the great facts which will be brought in more detail before the reader.

The globe, consisting originally of matter in a state of igneous fusion, being put in a state of rotation, assumed, as a necessary mechanical consequence of that motion, the form which it still retains, called in geometry that of an oblate spheroid, flattened at the poles and bulging out at the equator; the sections made by planes passing through the axis of rotation being therefore ellipses, the longer axes of which are diameters of the equator. We have shown in former Tracts that the eccentricity or degree of the oval shape which characterises these ellipses depends immediately upon the velocity of rotation, so much so that, by mere mathematical calculation, the form of the ellipse has been deduced *à priori* from that velocity, and the form thus calculated has been found to correspond with the actual shape of the earth.

By the gradual process of cooling produced by radiation the surface of the earth became solidified, a thin skin of solid matter being first formed upon it, which, as the cooling continued, became gradually thicker, the increase of thickness being produced by more and more solidified matter collected on its inner surface. This thickness may be said therefore to have increased from the outside inwards. At first the temperature was necessarily such that water could not exist upon it in the liquid state, but according as the temperature of the surface became gradually lower, the aqueous vapour till then sustained in the atmosphere was more or less condensed and precipitated, forming upon it an ocean of uniform depth extending over the entire surface.

188. If no convulsion had taken place the earth would have continued in this state. It would have been one universal ocean undiversified by land, and the human race could never have existed upon it. It follows, therefore, that before terrestrial tribes were created the globe must have been of necessity the theatre of various catastrophes, by which the land was raised above the waters, and by which a state of things was established, more or less analogous to that which geography now presents to us. It was necessary, in a word, that the "dry land should appear."

2

Extensive observation on the condition of the crust of the earth proves that such forms were not assumed definitely and permanently at once, but that they underwent a long succession of changes, in the course of which the outlines of land and water were frequently varied: what was land at one time became the bottom of the ocean at another, and what was the bottom of the ocean at one time, rising to the surface, assumed the forms of continents and islands at another.

It would be easy to show, by an analysis of the effects produced by such a succession of catastrophes, that they all tended to one definite end; namely, the final adaptation of the earth for the dwelling-place of the human race, and its contemporaneous tribes.

After the superficial temperature had fallen sufficiently low to allow of the deposition of water upon the surface, and the formation of an universal ocean, a series of convulsions commenced, each of which was produced by the agency of the matter in igneous fusion contained within the solid shell of the earth. This matter acting unequally against the inner surface of the shell cracked it from time to time, producing fissures, through which the igneous pasty matter issued, cooling and solidifying when exposed to the external atmosphere. Each convulsion necessarily changed the relative levels of different parts of the solid surface, and this was attended with a corresponding change in the distribution of the waters of the ocean. Upon the occurrence of each phenomenon, these waters would rush with furious impetuosity over such parts of the land as would fall to a lower level, while at other places the solid bottom of the ocean would rise above the surface of the waters, forming new continents and islands. Such catastrophes must not be regarded as either conjectural or imaginary. They have, on the contrary, left on the earth visible traces by which their occurrence has not only been demonstrated, but even their dates have been geologically ascertained, so that we are enabled to state the order in which they occurred.

189. For a long period of time, during which these catastrophes were developed at intervals, the superficial temperature depended infinitely more upon the internal heat transmitted to the surface through the crust, than upon the effects of solar radiation. It must be remembered, that, so far as the superficial temperature would depend upon the heat received from the interior through the crust, the temperature would be everywhere the same. Thus it would affect the poles and the equator equally, and would be equally diffused over all latitudes; but, on the contrary, so far as the temperature would depend on solar radiation, it would vary with the latitude, as it does at present, being greatest between the tropics, and least

within the polar circles. But, as has been just observed, during the early periods of the history of the earth, to which we now refer, the influence of internal heat predominating enormously over that of solar radiation, the effects of the latter were wholly effaced, and, consequently, the superficial temperature was uniform at all latitudes.

190. For a long period after the commencement of superficial solidification, this temperature was far above the limit compatible with the existence of any form of organic life, animal or vegetable; and, consequently, during this interval the globe was a mere waste, unanimated by life and unadorned by vegetation. Meanwhile, nevertheless, a succession of changes took place, the effects of which have remained so visibly traced upon the earth to the present day, that geologists have been enabled to pronounce not only their existence but their order. Four times the solid crust was cracked, and the internal fluid matter issued through the fissures, forming four systems of mountain-ranges, which still exist to attest these remarkable facts in the primitive history of our planet.

191. At length the temperature being reduced to a point compatible with organised life, creative power began to be manifested. The earth was peopled with animals and clothed with vegetation, but these animals and this vegetation differed altogether from those which now animate and cover the globe. They were, however, adapted by divine wisdom to the then condition of the earth, the temperature being not only greater than any which prevails at present, but, as has been stated, uniform at all latitudes.

192. After this, a like succession of convulsions took place, long intervals of time intervening, by each of which the relative levels of the land were changed, and consequently the distribution of the waters of the ocean completely altered. Such changes implied universal inundations, which involved the destruction of all animated nature, animal as well as vegetable. In short, a succession of deluges must have attended such convulsions, each deluge destroying all the tribes of animals and plants which existed on the globe at the time of the catastrophe.

193. After each of these convulsions, the waters at first turbid, and holding in suspension great quantities of matter washed away and eroded from the former land, as well as enormous quantities of the remains of the animals and plants previously existing, would, after a time, become tranquil, and then a process of vast importance to the preservation of the history of the globe would take place. The organic remains of animals and plants suspended in the waters would be deposited at the bottom

of the ocean, and over them would subside also the solid matter sustained in a state of comminution in the waters. The remains would thus be buried in strata sensibly horizontal, and, being covered up by the earthy and mineral matter which would subside from the waters, they would be protected from the destructive action of air and water thereafter, and would thus be preserved to future generations as records of the past history of the earth.

In the interval of tranquillity following each such deluge, creative power was again brought into operation, and the earth was repeopled with animated creatures, and reclothed with vegetation; but in all cases the animals and plants composing the new kingdoms of nature, though agreeing with those recently destroyed in their classes and generic characters, differed from them altogether in their species. In short, a new kingdom of nature was produced, but constructed upon the same general principles.

194. By researches made in the crust of the earth, and careful analyses of the constitution of its strata and of the animal remains contained in them, geologists have ascertained, with a high degree of probability, if not with absolute moral certainty, that subsequently to the first appearance of the forms of animal life, which, as has been stated, took place after the fourth great convulsion of the globe, there were at least twenty-eight successive convulsions of a like nature, each of which was attended with the complete destruction of the animals and plants which existed upon the globe, their remains being buried in the manner already stated under the sedimentary deposits made by the new oceans which followed the crisis.

The actual occurrence of these several convulsions, and of the existence of the successive animal and vegetable kingdoms, differing one from another in the species of which they were constituted, has been proved by geologists by two species of evidence, one depending on the condition of the stratification, by which it has been shown that many of these catastrophes were attended with the elevation of systems of mountains which still exist upon the surface of the earth, while others, though not indicated by mountain ranges, are rendered evident by certain discordances and disturbances in the state of the strata. These catastrophes have also been indicated by the discovery of the buried remains of each of the several animal and vegetable kingdoms here mentioned.

195. In fine, after the latest of the catastrophes, when the last strata of the tertiary formation were deposited, the most recent exertion of creative power took place, and the globe was peopled with the tribes which now inhabit it, including the human race.

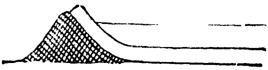
Such is a brief and rapid sketch of the phenomena which form the subject of the pre-Adamite history of the globe, which it is our present purpose briefly to sketch.

196. The manner in which the geological age of mountain-ranges is determined by the state of the strata observed upon their slopes has been already explained, but this is so important an element in our present inquiry, that it may be useful to recapitulate it and present it to our readers under another aspect.

When we see anywhere the sedimentary strata composing the crust of the earth inclined, we can pronounce with certainty that they have been disturbed from their original position which was horizontal, and that, in short, an elevation has taken place by a force acting from beneath. So far as relates to the strata thus inclined, the epoch of the catastrophes would be undetermined, but if at the foot of the mountains we find other strata *a b c*, fig. 112,

Fig. 112.

Fig. 113.



horizontal, it becomes evident that the elevation of the former must have taken place before the deposition of the lowest of the latter, since the latter are in the position in which they naturally subsided from the waters.

The geological date of the elevation in this case would be between the period of the strata, which are elevated and inclined, and the lowest, *a*, of the horizontal strata. In the case of all mountain-ranges, data of this kind, determining the geological epochs of the disruption which produced them, are supplied. In some places we see for example the stratum *a*, heaved upwards, and *b* horizontal, fig. 113. In such cases the date of the catastrophe is posterior to the deposition of *a*, and anterior to that of *b*.

Fig. 114.

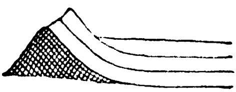


Fig. 115.

In other cases, both *a* and *b*, fig. 114, are uplifted and inclined, but *c* is horizontal, and it is accordingly inferred, that the date

of the catastrophe was between the deposition of the strata *b* and *c*.

In like manner if it be found that while the strata *a*, *b*, and *c* are all uplifted and inclined, *d* is horizontal, fig. 115, it is inferred that the date of the catastrophe was between the periods of the deposition of *d* and *c*, and so on.

It will be evident that we have here assumed that the strata *a*, *b*, *c*, *d*, &c. are in the natural succession of strata, in the order of geological time, found in any complete section of the earth's crust, in which no strata are deficient.

197. It must also be observed that the direction of the inclination of the strata thus uplifted, corresponds with and determines the direction of the ridge of mountains upon the flanks of which they lie, and it has resulted from the extensive and profound researches of M. Elie de Beaumont, that the chains of mountains in general whose directions are parallel have the same geological date, as is proved by the strata inclined upon their sides and horizontal at their base. Mountain ranges, therefore, which until the discovery of this important law were regarded as geologically distinct and independent, are now brought into the same system. Each mountain system, therefore, must be regarded not as a single chain, but as a number of parallel chains which may be near or distant from each other within any assignable limits. It may also be observed, that the parts even of the same chain are not always continuous, but may be broken by intervals along which, as it were, the crust sinks to the level of the surrounding plain.

198. The systems of mountains which have thus been grouped according to their geological dates have usually received denominations from some remarkable locality in which their prevalence is most conspicuous. Thus one is called the system of the Pyrenees, another the system of the principal Alps, another the system of the western Alps, and so on.

The different convulsions which have taken place upon the surface of the globe, and which have produced the several mountain systems, seem to have been always sudden. In effect at some distance from the place where the discordance of the stratification manifests former convulsions, the same strata are found concordant and horizontal, from whence it follows, that in such cases the sedimentary deposition has not been suspended, the disturbance of the crust has been local, and the interval during which it has prevailed has necessarily been short.

199. During each successive geological period, the earth has been differently divided into land and water, the continents and islands of one period being submerged during another, and the

parts submerged becoming dry land. During each period the deposition of strata corresponding to it, has been of course confined to such parts of the earth only as were covered by water, and hence we are able to trace the geographical limits of sea and land, by tracing the limits of the deposits characteristic of each stratum.

Thus, during the Silurian period, the Silurian strata have been deposited only on those parts of the globe which were during that period covered by water, but not on those which formed the land. When we use the expression, therefore, the *Silurian sea*, we must be understood to mean that portion of the globe which, during the Silurian period, was covered by water, and those portions must necessarily be co-extensive with and limited by Silurian deposits. In the same manner during the Cretaceous period, the globe, as before, consisting of land and water, the cretaceous deposit was made only in those parts which were then covered by water, and formed the bottom of what is called the *Cretaceous sea ;* the other parts of the earth, which at that epoch formed the land, being consequently destitute of the cretaceous strata.

In the same sense is to be understood the expressions, the *Triassic sea*, *Jurassic sea*, *Tertiary sea*, and so on.

The absence, therefore, of any particular deposit in an extent more or less considerable of the crust of the earth, indicates that the subjacent deposit was above the level of the sea, and formed an island or continent more or less elevated during the period in which the absent deposit was made. Thus, for example, an extensive plateau in the centre of France must have been dry land from the most remote geological epochs; and at the epoch of the formation of the deposit which constitutes the present Paris basin, the greatest part of Europe must have been dry land, while Paris and a large tract surrounding it, as well as Bordeaux and the surrounding regions, were covered by the sea, as will be more fully explained hereafter.

But it happens also that the parts which thus prove to have been dry land at a certain geological epoch, have been afterwards covered by more modern sediments; from whence it follows that they must have subsequently sunk beneath the ocean, so as to receive these new deposits. It is by such subsidences of the land that some of the geological convulsions, whose traces will be hereafter noticed, have been explained.

200. According to the results obtained from the researches of M. Elie de Beaumont, it appears from a comparison of the various mountain ranges of Europe, and from an examination of the strata upon their slopes and at their bases, that since the solidifi-

cation of its crust this part of the globe has undergone at least seventeen distinct convulsions, each of which has produced a mountain system, the mean direction of which has been ascertained, and is characteristic of it. These seventeen systems have received denominations, as already mentioned, from some localities in which their prevalence is most conspicuous, and the directions which characterise them are indicated in the following diagram.

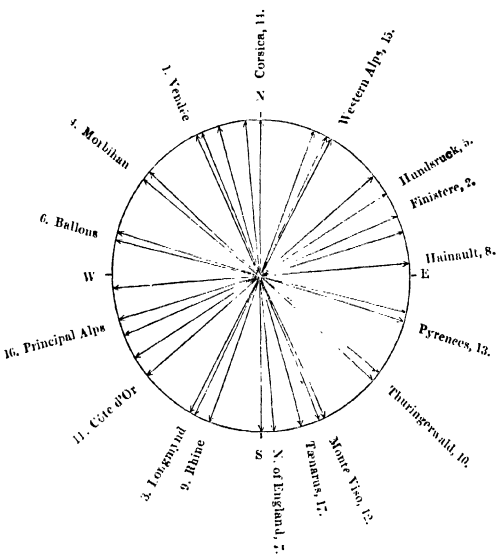


Fig. 116.—Directions of the principal Mountain-systems.

201. The order in which these several systems have been elevated is indicated by the numbers placed at one extremity of the lines indicating their direction, and these directions are expressed with more numerical precision in the following table, where W. 21° S. means a point 21° south of west; N. 23° E., a point 23° east of north; W. 38° N., a point 38° north of west, and so on. The places indicated in the second column are those from which the system takes its name, and those indi-

cated on the fourth column those at which its direction has been determined.

1st	Vendée	N. N. W.	Vannes.
2nd	Finistère	W. 21° S.	Brest.
3rd	Longmynd . . .	N. 23° E.	Vannes.
4th	Morbihan	W. 38° N.	Vannes.
5th	Hundsruck . . .	W. 31° S.	Bingerloch.
6th	Ballons	W. 15° N.	Ballons.
7th	North of England . .	N. 5° W.	North of England.
8th	Hainault	W. 5° S.	Netherlands.
9th	Rhine	N. 21° E.	Upper Rhine.
10th	Thuringerwald . .	W. 40° N.	Thuringerwald.
11th	Côte d'Or . . .	W. 40° S.	Côte d'Or.
12th	Monte Viso	N. N. W.	Monte Viso.
13th	Pyrenees . . .	W. 18° N.	Pyrenees.
14th	Corsica	N.	
15th	Western Alps . .	N. 26° E.	Alps of Dauphiné.
16th	Principal Alps . .	W. 16° S.	Alps of the Valais.
17th	Tænarus		Greece.

202. In laying down upon the map the directions of the several systems, their divisions into such as run between N.W. and S.E., and between N.E. and S.W., becomes very apparent, as will appear by reference to fig. 117, in which the several systems are indicated by peculiar marks as follows:—

1. Vendée.
2. Finistère.
3. Longmynd.
4. Morbihan.
5. Hundsruck.
6. Ballons.
7. North of England.
8. Hainault.
9. . . . Rhine.
10. Thuringerwald.
11. Côte-d'Or.
12. Monte Viso.
13. Pyrenées.
14. ++++++ Corsica.
15. Western Alps.
16. Principal Alps.
17. Tænarus.

203. The systems directed between the N.W. and S.E. run from the Rhine towards Provence and Brittany, and those between the N.E. and S.W. from Normandy, Brittany, and the Pyrenees towards the Apennines.

204. The geological dates of these several systems of elevation, determined, as will presently appear by the position of the strata on their flanks and at their bases, are as follows:—

I. System of Vendée raised before the deposition of the Cumbrian group.

II. System of Finistère raised between the Cumbrian and the green slate of Longmynd.

III. System of Longmynd raised between the Longmynd slate and the Bala limestone.
IV. System of Morbihan raised between Bala limestone and the Silurian deposit.
V. System of Hundsruck raised between the Silurian and Devonian.
VI. System of Ballons raised between the Devonian and carboniferous.
VII. System of North of England raised between the carboniferous and Permian.
VIII. System of Hainault raised between the Permian and Vosges sandstone.
IX. System of Rhine raised between the Vosges sandstone and Triassic.
X. System of Thuringerwald raised between the Triassic and Jurassic.
XI. System of Côte d'Or raised between the Jurassic and lower cretaceous.
XII. System of Monte Viso raised between the lower and upper Cretaceous.
XIII. System of Pyrenees raised between the upper Cretaceous and lower Tertiary.

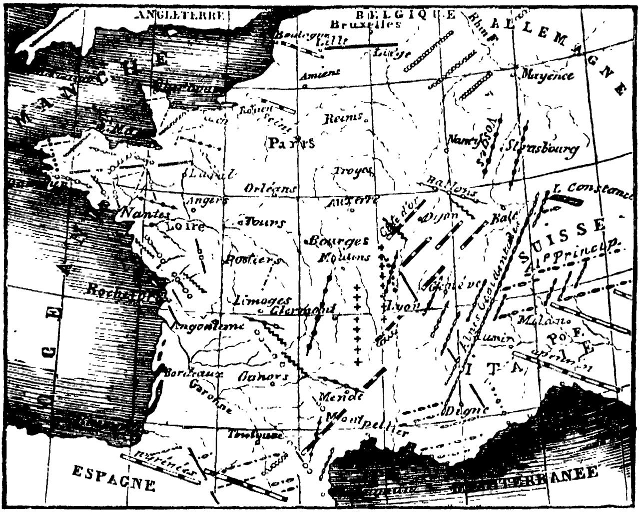


Fig. 117.—Map of France, showing the prevailing direction of the principal systems of mountains.

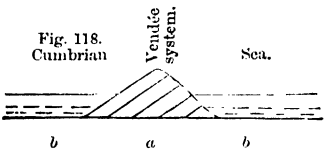
XIV. System of Corsica raised between the lower and middle Tertiary.
XV. System of Western Alps raised between the middle and upper Tertiary.
XVI. System of principal Alps raised between the upper Tertiary and Diluvial.
XVII. System of Tænarus raised between the Diluvial and Alluvial.

205. We shall now briefly explain the stratigraphical characters by which these several dates have been ascertained.

I. SYSTEM OF VENDÉE.—In the earlier researches of M. Elie de Beaumont, the Hundsruck system, the elevation of which appeared to precede immediately the Silurian period, was assumed to be the earliest catastrophe of that kind of which the crust of the earth afforded any evidence. Observations more multiplied and exact, and a more elaborate discussion of the phenomena, discovered by his own labours and those of other geologists, have, however, conducted him to the conclusion that four of the existing mountain systems were produced at much earlier epochs.

The first of these, to which the French province of La Vendée has given its name, is represented with the Cumbrian beds horizontal at its base, in the section fig. 118, where *a* represents the mountain range, and *b* the Cumbrian deposit.

Fig. 118.



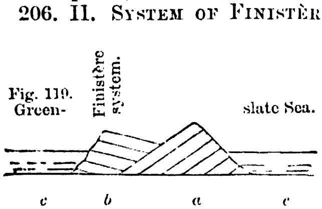
We may therefore imagine *b* to be the sea of the epoch, which succeeded this elevation, in the bottom of which the Cumbrian formation was deposited. It is in this sense that the *Cumbrian sea* is to be understood, and a like form of expression will be used in a corresponding sense in other cases.

The date of the catastrophe by which the Vendée system was pushed up, must therefore be prior to the deposition of the Cumbrian strata.

This mountain system has hitherto been but little studied. Traces of it are shown by M. de Beaumont to exist in schists of Belle-Isle, of the embouchure of the river Villeine, in the mica-schists or gneiss on the banks of the river Blavet (dep. Morbihan), in Beaupréau, and Bourbon-Vendée.

206. II. SYSTEM OF FINISTÈRE.—By the catastrophe which produced this system, the Cumbrian formation *b*, fig. 119, was uplifted, and in the period of tranquillity which followed, the waters deposited the strata of green slate of Longmynd in Wales. These last, *c*, are accordingly seen in horizontal strata along the base of the system.

Fig. 119.



The date of the catastrophe is therefore posterior to the deposition of the Cumbrian formation, and anterior to that of the green slate of Longmynd and Westmoreland.

Traces of this system exist in the gneiss and mica-schists of Brest, the Cumbrian schists between Pontivy and Falaise, the chloritic schists of Cherbourg, the Cumberland ranges, and at Gotheburg and Upsal in Sweden, whence it is continued into the southern part of Finland. It is also seen in the Pyrenees and in Catalonia.

207. III. SYSTEM OF LONGMYND.—The green slate deposits were forced up and inclined by this convulsion, and in the tranquil period which ensued, the Bala lime-stone beds, *d*, fig. 120, were deposited by the ocean on their flanks, where these strata are still seen in the same horizontal position.

Fig. 120.

The date of the catastrophe is therefore posterior to the lime-stone.

In Brittany the green slate does not appear between the Bala limestone *d* and the Cumbrian strata *b*, which shows that that part of Europe was dry land while the Bala sea was making its deposits.

The stratification due to the Longmynd system has been traced in Limousin in France, in the mountains of Morocco, in the Serra da Estrella in Portugal, in the Erzgebirge in Saxony, in the gneiss mountains of Moravia, and of those parts of Bohemia bordering on Austria, on the north-east of the Wenner lake in Sweden, along the coast of the Gulf of Bothnia in Finland, and along that of Wiborg on the other side.

208. IV. SYSTEM OF MORBIHAN.—The convulsion which produced this system upheaved the Bala formation *d*, fig. 121, throwing its strata, previously horizontal, into an inclined position. In the tranquil period which ensued, the mountains thus formed were washed by an ocean and seas in which were deposited the Silurian formation *f*, which is still horizontal, on the flanks of this system.

Fig. 121.

This convulsion, therefore, immediately preceded the Silurian period, and was posterior to the deposition of the Bala limestone.

The system of Morbihan is very extensive; it is traced in the mica-schists and gneiss of the Loire Inférieure, in the islands which terminate the south-west coast of Brittany, in the granitic plateau which extends along that coast beyond Parthenay, and over part

13

of the Limousin, where traces of it appear between Tulle and Nontron. It is found also in the north-eastern part of Brittany and in the Bocage of Normandy. Traces of it are found in the mica-schists and gneiss of Messina, in the Erzgebirge, in Bœhmerwaldgebirge, in the granitic steppes which extend from Volhynia towards the Don, in Labrador and in Canada.

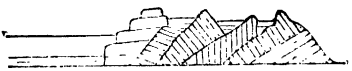
209. V. System of Hundsruck.—The catastrophe which produced this system coincided with the commencement of animal and vegetable life upon the earth. The strata deposited by the waters of the Silurian sea which preceded it, were uplifted from their horizontal position so as to form the mountain ranges to which M. Elie de Beaumont has given the name of *Hundsruck*, from a mountainous region of Germany extending over the southern part of Rhenish Prussia and Rhenish Bavaria, where it is connected with the chain of the Vosges. Its geological date is fixed by the fact that the Devonian strata are found in a horizontal position upon its flank, as shown in fig. 122. The catastrophe must, therefore, have followed the Silurian, and preceded the Devonian period.

Fig. 122.

This system is traced through France, in Brittany, in the department of the Ille-et-Vilain, in the strata which cover Cape Finistère, in Mayenne, and in the department of the Orne and the Manche. It appears also in the slate formation of the Ardennes, of the Eiffel, in the mountains of Hundsruck and the Taurus. It is also found in the Hartz mountains, in the Erzgebirge, in Bohemia, in the island of Gothland, in Finland and Lapland. In England it is traced in Cornwall, Westmoreland, and the Grampians.

210. VI. System of the Ballons.—This system originated in a convulsion by which the Devonian strata, *g*, were uplifted and thrown into an inclined position, as shown in fig. 123. The waters of the globe, when tranquillity ensued, deposited the carboniferous beds in horizontal strata, *h*, in the bottom of seas, oceans, and lakes, the latter being at more elevated levels than the former, as shown in the figure.

Fig. 123.



The date of the catastrophe is, therefore, antecedent to the carboniferous, and posterior to the Devonian period. This system is

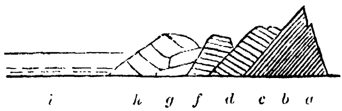
traced in France in the anthracite schistous beds on the banks of the Loire and of the Brest canal. It is also seen in the department of Mayenne, in the south-east of Laval, in the southern part of the Vosges, in the chains of Lozère, Margeride, and the Corrèze.

In England the system is directed from Cornwall to the Grampians, in Belgium from Avesnes to Liège, and in Germany in the Hartz mountains, which probably have received from it their peculiar form.

It may also be traced in Bohemia, Saxony, Sweden, Russia, Siberia, in the Altaï range, in North America, along the line of the Alleghanies, and in southern Asia.

211. VII. SYSTEM OF THE NORTH OF ENGLAND.—The convulsion which produced this system dislocated the coal formation, *h*, fig. 124, and in the tranquil period which succeeded the waters of the ocean deposited the Permian strata, *i*.

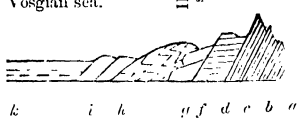
Fig. 124.
Permian sea.



Its date, therefore, was prior to the Permian and subsequent to the carboniferous period. This system is characterised by lines of summit which extend from the parallel of Derby to the frontiers of Scotland, through Yorkshire, and between Cumberland and Northumberland. Traces of it are also found in the neighbourhood of Bristol, as well as in the south of Ireland. It is traced also both in Norway and Sweden, upon the crests of the southern chains.

212. VIII. SYSTEM OF HAINAULT.—The catastrophe which produced this system has been manifested less by any elevated ridges than by a series of dislocations and compressions which are seen in England, between Pembrokeshire and Mansfield, and which also traverse the Netherlands, running nearly east and west. All the existing strata, and particularly the coal measures, *h*, fig. 125, and the Permian strata, *i*, exhibit these effects.

Fig. 125.
Vosgian sea.

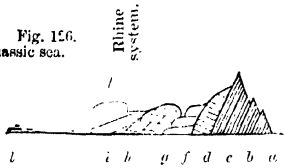


The strata of Vosgian sandstone are, however, undisturbed and horizontal as they were deposited from the waters, showing that the date of this catastrophe was anterior to their deposition and posterior to the Permian period. These positions of the Vosgian strata are apparent at Sarrebruck.

Traces of this system are found between Liege and Lille, in the direction of certain granitic islets, in the coal basin of Brittany, and from Laval towards Quimper.

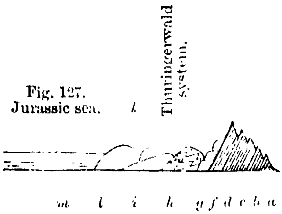
213. IX. SYSTEM OF THE RHINE.—This system is manifested chiefly upon the cliffs of the Rhine, between Bale and Mentz, with various other parallel escarpments, indicating faults which have affected all the strata, including the Vosgian sandstone, *k*, fig. 126, patches of which they have pushed up to different heights, without disturbing their horizontal position. Hence have resulted islands in the seas of this epoch, around which the Triassic group has been deposited at a lower level, as shown in fig. 126.

Fig. 126.
Triassic sea.



214. X. SYSTEM OF THURINGERWALD.—The mountains to which this system has given its name, and of which the Bœmherwaldgebirge is the continuation, constitute the natural frontiers which divide Bavaria, Saxony, and Bohemia. The most remarkable effects of this catastrophe are manifested between Cassel and Linz, where the Triassic strata, *l*, are uplifted and overlaid by the Jurassic deposits, *m*, in level strata, fig. 127.

Fig. 127.
Jurassic sea.



Some traces of this system are seen in the south-western part of the Vosges, where the Triassic strata (*grès bigarré*) are raised considerably above the general level, an effect probably produced by the masses of serpentine which protrude in that region. Between Avallon and Autun some granitic islets and dislocated Triassic strata have also the north-west direction, and are surrounded by the Jurassic limestone in level strata. The date of the catastrophe is, therefore, anterior to the Jurassic period, but posterior to the Triassic.

Fig. 143.—FOSSIL SCORPION (CYCLOPHTHALMUS BUCKLANDII).

THE PRE-ADAMITE EARTH.

CHAPTER II.

215. Elie de Beaumont's mountain systems continued: System of Côte d'Or. —216. System of Monte Viso.—217. System of the Pyrenees —218. System of Corsica.—219. System of the Western Alps.—220. System of the Principal Alps.—221. System of Tænarus.—222. Principal effects of this convulsion.—223. Extension of De Beaumont's system by analogy to the remainder of the globe ; general plan of mountain systems.—224. Geological horizon explained ; mineralogical characters insufficient to identify it.—225. Indications supplied by fossiliferous deposits. — 226. Twenty-nine fossiliferous strata. — 227. Zoological stratification.—228. Method of determining outlines of land and water twofold : mineralogical and zoological.—229. The mineralogical tests uncertain.—230. The zoological tests clear and definite.—231. Organic remains which characterise the bottom of deep seas.—232. Organic remains which determine the shores of seas.—233. Others which determine the bottoms of shallow seas.—234. Others which indicate the embouchures of rivers and estuaries.—235. Conventional terms.—236. Successive creations.—237. Geological periods and stages.—238. Six great formations.—239. Resolution of the earth's crust into 29 stages. —240. Six geological ages.—241. Succession of geological periods.—

242. Zoological terms: four principal divisions of animals.—243. Subordinate nomenclature.—244. Table of the classes of animals.—245. Zoological characters of the principal divisions.

215. XI. System of Côte d'Or.—This system in its direction is nearly at right angles to the preceding, see fig. 116. The Jurassic deposits, *m*, fig. 128, are pushed up, and the lower cretaceous strata, *n*, ranged horizontally upon them, as shown in fig. 128. This system may be traced without interruption from Luxembourg to Roehelle, and in all the crests of the Jura. It was by this catastrophe that the eastern border of the central plateau of France was raised and dislocated after the formation of the Jurassic group, which is there considerably elevated; while the other borders have suffered no derangement: which indicates that this plateau, in the chief part of its extent, has undergone no change since the Jurassic period. Traces of this catastrophe are also manifested in several other parts of France—north and south; in several parts of Germany; and especially in the Erzgebirge, which, though divested of the Jurassic limestone, has the lower cretaceous strata in horizontal beds at its foot.

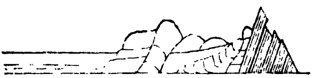
Fig. 128. Lower cretaceous sea. Côte d'Or system.

n *m* *i* *h* *g* *f* *d* *c* *b* *a*

The date of this catastrophe is, therefore, between the period of the deposition of the lower cretaceous strata and that of the Jurassic group.

216. XII. System of Monte Viso.—The dislocation of the lower cretaceous deposits, *n*, fig. 129, by this catastrophe, and the presence of the upper cretaceous deposits in their horizontal position, are distinctly manifested in the Alps of Dauphiné, showing that the date of the catastrophe is between the periods at which the upper and lower cretaceous deposits were made.

Fig. 129. Upper cretaceous sea. Monte Viso system.



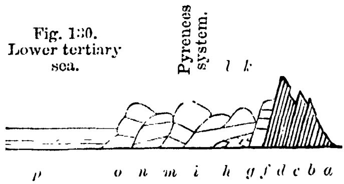
o *n* *m* *i* *h* *g* *f* *d* *c* *b* *a*

The upper cretaceous strata, represented by beds of nummulites, and sometimes, but very rarely, by grey and compact limestone, are alone found to be horizontal, as may be seen on the Col de Bayard and the Col Maurin. Indications of this system may also be traced at the south of Grenoble, in the north of Dauphiné,

in the mountains which connect the Alps with the Jura, as far as the Pont d'Ain and Lons-le-Saulnier. It was this catastrophe which determined the principal direction of the coasts of Italy, as well as that of a system of elevated ridges in Greece, of which Pindarus forms part.

217. XIII. System of the Pyrenees.—By this catastrophe the upper cretaceous strata, *o*, fig. 130, were raised and dislocated.

Fig. 130.
Lower tertiary sea.



The lower tertiary strata, *p*, being horizontal, show that the date of the catastrophe is between that of the lower tertiary and the upper cretaceous periods. By this disturbance the upper cretaceous strata have been elevated to a considerable height, forming lofty cliffs, especially along the Spanish frontier.

The calcareous strata of the Paris basin, usually considered as the lowest of the tertiary strata, having but little extent over the surface of France, or even of Europe, it follows that at the epoch of the formation of the Pyrenean system, the chief part of the continent of Europe was suddenly raised above the waters and rendered dry land.

Not only the whole chain of the Pyrenees, as well in France as in the Asturias, belongs to this epoch, but also that of the Apennines, the Julian Alps, the Carpathians, the Balkans, and the mountains of Greece. The same direction is discovered in numerous dislocations and denudations in Germany, in the north of France, and in the Wealden of England; from whence it appears that this catastrophe must have had a vast extent, affecting certainly the entire surface of Europe and probably of the world.

218. XIV. System of Corsica.—This catastrophe, unlike the former ones, is not marked by an elevation of the strata, which were formed under the water. After the preceding elevation, the Parisian lime-stone, which would then be found, is completely absent in those places where the new catastrophe was manifested.

The absence of this deposit signifies that the ground over the whole of Europe at that epoch was raised above the level of the sea; but as observation shows us that in this same place other marine deposits were made at a later period, it must be concluded that those parts which were first elevated above the ocean sunk below it at a subsequent period, so as to receive the superjacent deposits now found upon them. This must in fact have happened to part of the Paris basin, to Touraine, the chief part of Gascony,

all Switzerland, the valley of the Rhone from Lyons to the sea, as well as to several parts of Italy, Corsica, and Sardinia, which, not exhibiting any of the Parisian deposits, must have been brought above the level of the waters by the Pyrenean elevation, which produced the thirteenth system, and must have afterwards sunk to receive the subsequent deposits.

The Corsican system is manifested also by elevations and dismemberments, which have given their ultimate form to the mountains, which rising between the valleys of the Saone, the Loire, and the Allier, have directions from north to south. In these countries all the secondary strata are disturbed, and around them are formed the fresh-water deposits of Auvergne and the Loire. It was along the direction of this disturbance that were subsequently placed all the volcanic cones of the chain of the Puys.

Traces of this Corsican system are found in the mountains which connect the Alps with the Jura, in spite of the dismemberments which the succeeding catastrophes produced. There exists also a great number of chains having the same direction in the eastern and southern parts of Europe, in Tuscany, the Papal States, Istria, Albania, Greece, and so on. The islands of Corsica and Sardinia are also arranged from north to south, and present along the coast tertiary deposits in horizontal strata of the same age as those which are found in all the parts of France above mentioned.

219. XV. System of Western Alps.—If the Swiss Alps and those of Savoy and Dauphiné present traces of catastrophes which took place since the elevation of the system of Côte d'Or, it is not less evident that the actual profile of the chain has a date much more recent. In fact the middle strata of the tertiary system, which were only raised above the waters after the date of the Corsican system, are now elevated sometimes to vast altitudes, as well as the Jurassic and cretaceous formations beneath them. The only strata found horizontal are the upper tertiary. Thus it follows that this chain of mountains, which includes the most lofty in Europe, were not raised to their present elevation from the common level of the continent until after the deposition of the middle tertiary strata.

The matter which broke through the crust of the earth in this catastrophe, was the particular species of granite of which Mont Blanc and Monte Rosa are formed. A multitude of granitic islands in different parts of the continent are also formed of it, on the flanks of which appear inclined the tertiary, cretaceous, and Jurassic strata. These granites at an early epoch in the progress of the science, when the principles which determine the

dates of mountain ranges were less understood, being regarded as dating from the earliest geological periods, received the name of *Protogyne.* It is now known, however, that they did not break through the terrestrial crust until after the deposition of the middle tertiary system, seen in the strata around the Paris basin.

The relative position of the strata, determined by the elevation of the Western Alps, is illustrated in fig. 131, where the same letters are used to indicate the several strata, as in the former figures. The sea, which subsequently deposited in horizontal strata the upper tertiary system, is indicated in the figure.

Fig. 131.

This catastrophe produced not only the lofty chains of Savoy and Dauphiné, but extended its influence over Europe north and south. On the one side Nova Zembla and the whole Scandinavian Peninsula were affected by it, and on the other it produced a series of dislocations which are seen from Narbonne to Catalonia, determining the position of the whole Mediterranean coast of Spain. Its influence was felt south of the Mediterranean, producing the mountains of Morocco as well as those of the regency of Tunis.

220. XVI. System of principal Alps.—This catastrophe has produced the grandest features of relief upon the European continent. The lacustrine deposits, formed after the elevation of the Western Alps, were themselves dislocated by it, and along the foot of the chain there are no other horizontal strata than the diluvial deposits of the present epoch. The matter pressed up from the inner regions of the globe by this catastrophe were the different varieties of melaphyres, the sienites, the euphotides and serpentines, which forced up all the tertiary deposits of Piedmont and Provence, as well as the granitic rocks which constitute the most elevated summits of the principal chains of the Alps.

Not only were all the mountains which extend from the Valais and St. Gothard into Austria raised on this occasion, but the greater part of the surface of Europe shared in the movement. In fact the surface of the continent was lifted into a gentle acclivity, directed towards the line of summit of this great chain. It is thus for example that the plains of Bavaria rise slowly in a direction a little east of south, and those of Lombardy in an opposite direction. In the south of France, in like manner, the tertiary formation rises from the south towards the north, from

the borders of the Mediterranean to Saint-Vallier, and on the other side the inclination is in the opposite direction. From the borders of the Loire the surface rises gently on the one side in the direction N.N.W., and on the other in the direction S.S.E., as far as the valleys of Auvergne. At the foot of the Pyrenees, the ophites, as well as the gypsums and the saliferous masses connected with them, form a tract whose direction is parallel to the chain of the principal Alps, and resemble the arrangement of the serpentines of the valley of Aosta.

221. XVII. System of Tænarus.—This is the last and most recent great catastrophe of which Europe has been the theatre. It took place at an epoch when our seas were peopled by the tribes which now inhabit them, and when possibly the human race had already appeared, so that the result might not inaptly be called the *post-Adamite system*.

After the diluvial deposits which surrounded the principal Alps in horizontal strata had been made, the surface of Tuscany underwent a dislocation parallel to a great circle, directed nearly N.W. and S.E. The deposits raised at this epoch include nothing but shells, similar to those of the existing seas, as may be shown by an examination of the tufa of the Phlegræan fields, a district on the shore of the Bay of Baiæ, near Naples, and of the Somma of the island of Ischia. The sedimentary deposits of Sardinia, where M. de la Marmora discovered the remains of infant arts, appear also to have shared in this movement, which must therefore have been one of extremely modern date compared with all those already described.

222. It is to this catastrophe that must be ascribed the elevation of the Somma, of Stromboli, and of Etna, all of which would have been totally deranged if they had existed before the catastrophe of the principal Alps, by which so many ravages have been produced in all directions. To the same movement are probably also due the volcanic formation of Auvergne and the Vivarais, the ejections from which have issued from fractures and fissures produced by some of the antecedent catastrophes.

The system of elevation, the traces of which are seen in Provence, near Nice, in Sardinia, in Sicily, and in the Phlegræan fields, is parallel to the modern system, which Messrs. Boblaye and Virlet have indicated at the southern part of the Morea, and which they have called *Tænarus*, from the adjacent cape of that name.

223. Such then, according to the remarkably able and perspicuous analysis of M. Elie de Beaumont, is the history of the principal changes which the surface of the globe has undergone

from the first consolidation of its external crust to the present epoch. Since it has been found in Europe (the only part of the world which has hitherto undergone sufficiently accurate geological survey), that the various ridges which have the same or parallel directions belong to the same epoch of elevation, analogy would justify a similar inference respecting all parts of the globe, and we should naturally conclude that parallel lines of direction and contemporaneity of formation are interchangeable principles. It is at least interesting to examine from this point of view the principal chains which are known in different parts of the earth.

To show how far the results of these observations in Europe may be generalised by such analogies, M. Elie de Beaumont designed for M. Beudant the plan which, by their permission, we have reproduced in fig. 132, showing the generalisation of the classification of mountain systems according to their dates, as above explained.

It will be seen upon this chart that the direction of the system of the Pyrenees extends from the Alleghanies in North America to the Indian Peninsula by the Carpathians, Mount Caucasus, the mountains of Persia, and the Ghauts in India. To the south of this line there are several parallel ridges, such as those which run from Cape Ortegal in the Asturias to Cape Creux in Catalonia. Also the little range of Grenada, the mountains which surround the southern side of the desert of Sahara, intersecting the direction of the Atlas, and, in fine, the Apennines, the Julian Alps, and the mountains of Croatia and Roumelia, extending to those of the Morea.

The system of the Ballons, so closely related in direction to that of the Pyrenees, is also represented in the Alleghanies.

The direction of the system of the Western Alps is observed from Morocco to New Zealand, passing along the eastern coast of Spain, the south of France, and a great part of the Scandinavian peninsula. Parallel ridges are found in the Cordilleras of Brazil, in the regency of Tunis, in Sicily, at the point of Italy, and in Asia Minor. All the littoral range of the old continent, from the northern cape of Lapland to Cape Blanco in Africa, partakes of this direction.

The direction of the principal Alps is in accordance with numerous other ridges. Chains parallel to this direction are found in the Atlas, in Spain, and across the old continent to the China Sea, including Mount Olympus, the Balkans, the Taurus, the central chain of the Caucasus between the Black Sea and the Caspian; in the long series of mountains which extend through Persia and Cabul, including the Parapamisan mountains in Afghanistan and eastern Persia, the range of the Hindoo Koosh,

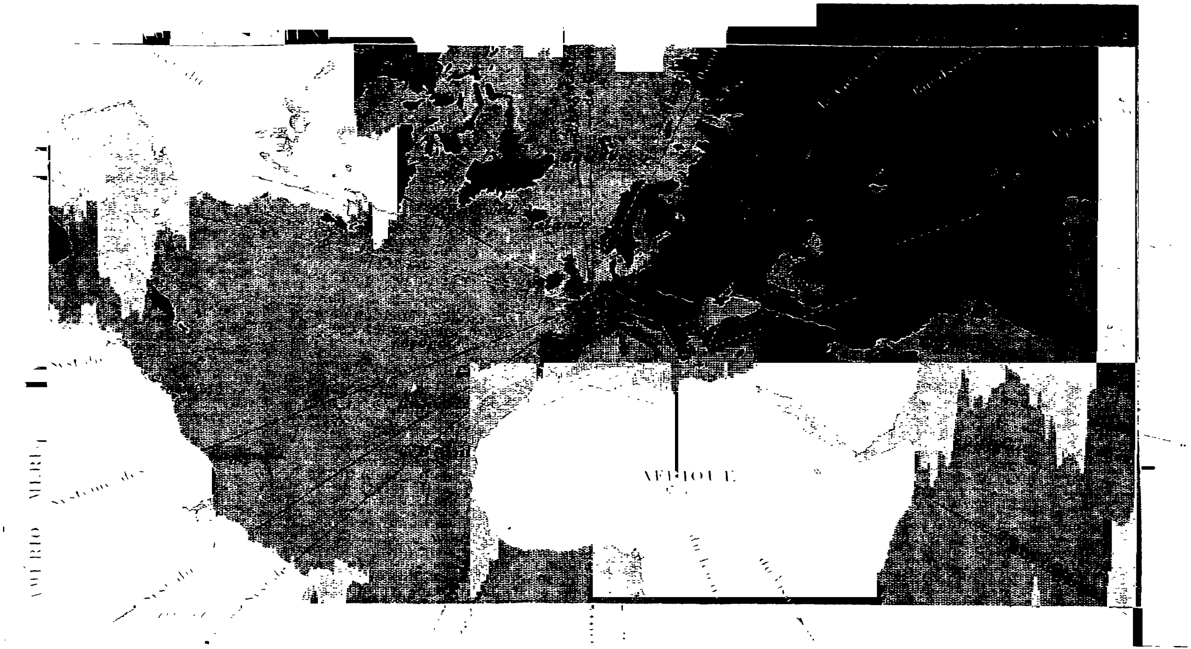


Fig. 132.—Plan showing the direction of the principal mountain systems according to the classification of M. Elie de Beaumont.

and, in fine, the Himalayas, which include the most lofty mountains in the world.

Parallel to the Corsican system are the chains of Syria and Palestine. Parallel to that of Monte Viso, those of Pindus. Parallel to the Thuringenwald are the mountains of Attica and Negropont. Parallel to the Côte d'Or, or perhaps the Hundsruck, are the Altaï range, and so on.

224. In all that has been hitherto explained the mineralogical components of the succession of strata are the only indications which have been given to determine each geological horizon,—a term to be understood as indicating that layer of the crust extending generally over the whole globe, which was contemporaneously deposited. If the waters of the oceans and seas of each epoch deposited everywhere a stratum composed of the same materials, and if the waters of no epoch anterior or posterior deposited like strata, then the mineralogical character of each stratum would supply certain indications of its date. But this has not been the case: on the contrary, strata which were incontestably deposited at the same epoch, are often composed in different places of different mineralogical constituents, while, on the other hand, strata of different epochs of deposition are sometimes found to consist of the same mineralogical components. Although, therefore, in a certain general sense, the mineralogical character of the strata, as has been explained, indicates the date of its deposition, yet when we come to define more exactly the successive geological horizons, these mineral characters cease to afford the necessary tests.

225. The indications which the mineralogical constituents of the strata have thus failed to supply, have happily been obtained from their fossiliferous deposits. From extensive observations, made both in the old and new world, it has been ascertained that in descending from stratum to stratum downwards, a succession of layers of organic remains have been found lodged within definite limits of geological level, the species found in each being almost totally distinct from those found in those above and below it. So that wherever we find the same organic remains, however different the strata in which they are lodged may be in their mineralogical character, we may conclude with certainty that they are of contemporaneous deposition.

226. Each fossiliferous stratum is distinguished from those above and below it, not only by the specific characters of its organic remains but also by its stratigraphic position, and, as we shall presently show, there are clear indications that the deposition of each such stratum, followed the destruction of the organic world by one of those violent convulsions which have been already described. Of these distinct fossiliferous strata twenty-nine

have been enumerated and connected with indications of as many geological convulsions, the result of each of which was the complete destruction of animal and vegetable life upon the globe, the fossil deposits of the next strata of the series in ascending, being the remains of the animal and vegetable tribes which re-peopled and re-clothed the earth after the ensuing period of tranquillity.

227. The organic remains, deposited in the successive layers of the terrestrial crust, show the character of the animal and vegetable world during the periods of tranquillity which followed the several convulsions which thus devastated the globe. It is, however, a problem of not less high interest to determine the geographical character of the surface, as defined by the relative extent and outlines of land and water, during each of these periods. The solution of this problem would be attended with no difficulty, if we possessed a perfect knowledge of the condition of the sedimentary strata in all parts of the earth. But not to mention our want of all knowledge of the state of that large portion of the earth's surface, which is at present covered with water, we have as yet been able to effect only a very limited and imperfect survey even of that lesser part which forms the land. Nevertheless, the positive knowledge, small as it is, which the labours and researches of geologists have supplied, aided by obvious analogies on which conclusions are based, having, if not in all cases moral certainty, at least a high degree of probability, has afforded a close approximation to the series of geographical changes which that part of the earth, at present composing the land, has undergone since the earliest geological epochs.

228. The means whereby the outlines of land and water at any proposed geological period are determined are twofold, one method depending on the mineralogical character of the strata, and the other upon that of its organic deposits.

To explain these methods, let us suppose, for example, that it is required to determine the outlines of land and water, upon those parts of the globe of which we possess sufficient geological knowledge, during the Silurian epoch. The first point will be, in that case, to determine the extent and limits of that class of strata to which the name Silurian has been given. Let us imagine that all the strata of more modern date are removed, and the Silurian strata laid bare. These strata were deposited during the Silurian period at the bottom of the seas and oceans which then partially covered the globe, and whose outlines and limits are the immediate subject of inquiry. The land during this period consisted of those parts of the globe alone upon which the Silurian deposit was *not made*. If, therefore, we possess the means of discovering the exact extent and outline of the Silurian deposit, we possess

all that is necessary for the solution of the proposed question. The outlines of this deposit are, in fact, identical with the outlines of land and water during the Silurian period. The land consisted, of course, of those strata which, being more ancient than the Silurian, were pushed above the level of the waters by the convulsion which preceded the period of tranquillity during which the Silurian strata were deposited.

229. If, therefore, the extent and limits of the Silurian deposit could be certainly and definitely ascertained, the problem would be solved; but independently of the knowledge, more or less imperfect, which direct observation has supplied as to the extent and limits of this deposit, some uncertainty attends the identification of the various strata to which the name Silurian is properly given, by their mere mineralogical characters. It has been already explained, that strata of simultaneous deposition vary in their mineralogical characters from place to place, those which have been deposited in one part of the world consisting of mineral constituents wholly different from those which have been deposited at the same epoch elsewhere.

230. The doubt which this raises, however, has been removed by the light thrown upon geology by fossil zoology and botany. If the mineralogical characters of contemporaneous strata be doubtful, there can be no uncertainty as to the zoological character of their fossil contents.

Although it be true that many of the genera of animals and plants, deposited in strata of different dates are common, this is not the case with the species which, with very rare exceptions, are peculiar to each period. If, therefore, the observer, guided merely by the mineralogical character of the strata under examination, be uncertain as to its date, his doubts will disappear upon a due examination of its organic deposits. No other than the strata of one particular epoch can contain the same combination of species of animals and plants.

231. But the aid afforded by the organic deposits is not limited merely to the determination of the date of the strata. They also supply the means of determining, with much greater precision than can be obtained from the mere mineralogical constituents, the outlines of land and water. It is known that certain genera of animals can live only in the tranquil bottoms of deep seas; there they live and there they die, and there their remains are buried in the strata deposited by such waters. Where such remains, therefore, are found in the strata of the crust of the earth, such strata must have been at the epoch of its deposition at the bottom of a deep sea or ocean.

232. The bodies of certain animals when dead and not dis-

membered, will float upon water. The remains of such would necessarily be washed upon the shore, and cast upon the coasts between high and low water-mark. There, upon the successive returns of the tide, they would be gradually covered with sand or mud, and would thus be buried in the strata to become future fossils. Where such remains are found, therefore, the strata must have been upon the very limits of land and water, upon the strand or coast surrounding continents or islands. If the floating bodies of such animals be dismembered, either by incidental fracture or by the voracious attacks of other living animals, their dismembered parts being, bulk for bulk, heavier than water, would sink, and in such cases would be deposited at the bottom of the sea. It must, therefore, be expected that such dismembered remains would be sometimes found in the fossil state, in juxtaposition with the complete remains of animals which live exclusively in the bottoms of deep seas; and such, in fact, is found to be the case. But from these indications, rightly understood, no doubt can arise, since in no case is the entire body of such an animal found in such a position.

233. Other marine animals live not on the very coasts of the sea, nor yet in very deep waters, but frequent the littoral parts of seas and oceans, and in the bottom of these their remains are accordingly found.

Without going, with any degree of tedious minuteness, into the zoological characteristics of the several marine tribes, it will, therefore, be understood, that the deposition of the complete remains of certain species can only take place on the coasts of seas and oceans between high and low water-mark, the deposition of others on the littoral parts, and of others again in the bottoms of deep seas.

Thus, according to the varying zoological characteristics of the organic remains, the geologist is enabled to pronounce in a definite manner upon the outlines of land and water.

234. The bodies of dead animals and uprooted vegetables are carried by the currents of rivers to their embouchures, and are there deposited, mixed with certain species of marine animals. Thus, the combination of fresh-water shells, land animals, and plants, with the remains of marine animals, are the sure indications of the embouchures of rivers and estuaries.

235. Having explained the indications by which the outlines of sea and land and the animal and vegetable kingdoms corresponding to them at each epoch of geological time can be determined, with more or less approximation, we shall proceed to relate the history of the earth, from the first appearance of animated nature upon it to the present epoch. It will, however, be convenient

previously to fix the sense of certain conventional terms necessary to be used in such a narrative, by which the effects of the succession of terrestrial convulsions, and the intervals of geological time will be expressed.

236. As has been already stated, the earth we inhabit has undergone a long series of convulsions, affecting its entire surface, each of which has been succeeded by a long interval of tranquillity, during which, the waters, in a state of equilibrium and quiescence, deposited the solid matter suspended in them in a series of layers, and in each of these intervals the author of nature called into existence an animal and vegetable kingdom, resembling more or less the present.

237. The intervals of time which elapsed thus between convulsion and convulsion, we shall call *geological periods*, and the mineral strata deposited by the waters during such periods, we shall call *geological stages.*

Unlike historic, geological time is therefore not measured by years and centuries. Its units are much more vast. Each of them is a *period*, that is an interval of time, whose exact length is unascertained, but which must be considered as having an analogy, more or less close, to the interval which will have elapsed between the creation of the present animal kingdom and the epoch, whenever it may arrive, at which, it, like all those which pre-existed, shall be swept away.

238. An analysis of the strata composing the crust of the earth has presented certain features, upon which geologists have founded a classification of the stages just mentioned. According to this classification, the stages, from the igneous rocks to the latest deposits, which immediately preceded the appearance of the present state of things, have been resolved into six groups, denominated as follows :—

1. Azoic formation.
2. Palæozoic formation.
3. Triassic formation.
4. Jurassic formation.
5. Cretaceous formation.
6. Tertiary formation.

239. The Azoic formation consists of groups of strata, the lowest of which reposes upon the igneous rocks. The Palæozoic formation rests upon the uppermost strata of the Azoic group, and in it, as its name implies, are found the first traces of organic life. The general stratigraphic characters of the other groups may be seen by reference to the tabular sections of the Earth's Crust, given in § 47.

The Palæozoic formation consists of five distinct stages, each

containing its own peculiar organic deposits. In like manner, the Triassic formation consists of two such stages, the Jurassic of ten, the Cretaceous of seven, and, in fine, the Tertiary of five; so that the whole fossiliferous portion of the earth's crust may be considered as consisting of twenty-nine stages, each stage being a catacomb in which the remains of the preceding creation are buried.

240. The intervals of time during which each of these six formations were deposited, we shall call *geological ages*. Thus, that in which the Azoic formation was deposited we shall call the *Azoic age*, that in which the Palæozoic formation was deposited we shall call the *Palæozoic age*, and so on.

241. The lesser intervals during which the several *stages* composing each geological *formation* were deposited, and during which, as already stated, an animated world was created, lived, and was destroyed, we shall call *geological periods*. Thus the Palæozoic *age* consisted of five *periods*, denominated in their numerical order, from the earliest or lowest to the latest or uppermost, the *first Palæozoic period*, the *second Palæozoic period*, and so on. In the same manner, the Triassic *age* consisted of two *periods*, the *first* and the *second*. The Jurassic of ten counted from the lowest, or most ancient, to the highest or most modern, and the like of the other formations.

242. Since it will be necessary to make frequent reference to the various forms of animal life, which from period to period prevailed upon the earth; and such references must occasionally necessitate the use of certain technical zoological terms, it will be convenient for those readers who are not already familiar with the elements of zoology, to give a general outline of the classification of animals which we shall adopt.

Naturalists have classed all the various forms of animal life into four primary divisions, denominated from their peculiar structure: 1. VERTEBRATA; 2. ANNULATA; 3. MOLLUSCA; and 4. RADIATA.*

243. Each of these primary divisions is resolved into a certain number of CLASSES; each class is again resolved into a certain number of ORDERS; each order is resolved into a certain number of GENERA;† each genus is resolved into a certain number of SPECIES, and each species consists of certain VARIETIES.

Here the classification terminates, the varieties being composed of individuals. Thus, if it be required to determine the zoological character of any individual animal, it is first necessary to state

* Much confusion prevails among the classifications adopted by naturalists; we shall, however, generally adhere to that of Cuvier.

† By an intermediate step, the orders are sometimes first grouped in *families*, and the families subdivided into *genera*.

the *variety* to which it belongs, then the *species* of which this is a variety, then the *genus* of the species, then the *order* of the genus, then the *class* of the order, and, in fine, the great primary division to which this class belongs.

244. The four primary divisions above mentioned are resolved into classes, as follows:—The *Vertebrata* into *four*, the *Annulata* into *six*, the *Mollusca* into *five*, and the *Radiata* into *five*, making altogether twenty classes, as shown in the following table.

CLASSIFATION OF ANIMALS.

	CLASSES.	EXAMPLES.
VERTEBRATA.	Mammifers	Man, ass, dog, horse, whale.
	Birds	Eagle, sparrow, cock, ostrich, duck.
	Reptiles	Tortoise, lizard, snake, frog.
	Fishes	Perch, carp, eel, skate, shark.
ANNULATA.	Insects	Bee, grasshopper, flea, butterfly.
	Myriapods	Scolopendra, Iulus. Figs. 133, 134.
	Arachnides	Spider, scorpion, mite.
	Crustacea	Crab, lobster, shrimp.
	Cirrhipeds	Anatifa (animals which attach themselves to ships' bottoms.) Fig. 135.
	Annelides	Earth-worm, leech.
MOLLUSCA.	Cephalopods	Octopus, cuttle-fish, nautilus. Figs. 9, 10, 11, p. 62.
	Gastropods	Snail, whelk.
	Lamellibranchia (acephala).	Oyster, mussel.
	Brachiopods	Lingula, terebratula, pentamerus. Figs. 18, 19, p. 66.
	Bryozoa	Reticulipora. Figs. 20 to 23, p. 67.
RADIATA.	Echinodermata	Star-fish, sea-urchin. Fig. 136.
	Polyparia, or Zoophytes	Coral, astrea. Fig. 137.
	Foraminifera	Figs. 104, 105, 106.
	Amorphozoa	Sponges, fungi. Figs. 138, 139, 140.
	Infusoria	Fig. 107.

245. The Vertebrate division is characterised by an internal skeleton and a cerebro-spinal nervous system. It takes its name from the vertebral or spinal column, to which all the subordinate parts of the skeleton are attached.

The Annulata have no internal skeleton, but in its stead a tegumentary covering, composed of movable rings, which gives them their characteristic form. Their nervous system consists of two long cords running longitudinally through the abdomen, twisted at intervals into knots called *ganglions*. The tegumentary covering, which is always annular, is sometimes hard and calcareous, as in the lobster and shrimp, and sometimes soft, as in the earth-worm and leech.

The Mollusca have neither internal skeleton nor articulated envelope. Their bodies are sometimes naked, but often protected by a shell.

The Radiata, including the lowest forms of organic life, is a group consisting of classes so heterogeneous, that many naturalists, not following Cuvier, have differently resolved them. They have in general no articulated skeleton, either internal or external, and scarcely exhibit the rudiments of a nervous system. Those to which the name Radiata is more properly applied are composed of organs disposed radially around a centre or axis.

Some naturalists have given to this division the name of ZOOPHYTES, from a Greek word, signifying the link between animals and vegetables; while others have confined this latter term to the Polyparia.

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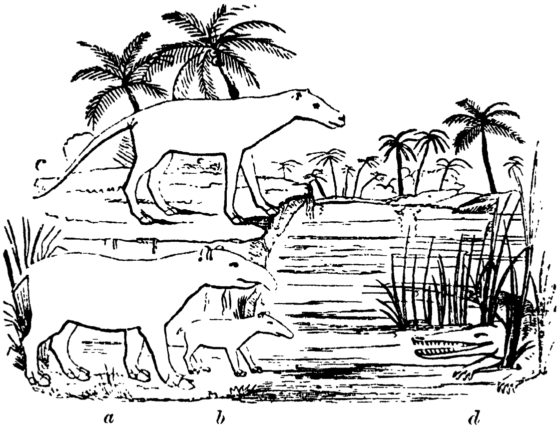


Fig. 182.—ILLUSTRATION OF THE ANIMAL AND VEGETABLE KINGDOMS DURING THE TERTIARY AGE.

a. Palæotherium magnum. *c.* Anoplotherium commune.
b. Palæotherium minus. *d.* Crocodile.

THE PRE-ADAMITE EARTH.

CHAPTER III.

246. Derivations of the names.—247. Examples of the classes.—248. Number of fossil species.—249. Their distribution in 29 stages.—250. These stages correspond to 29 periods.—251. Successive manifestations of creative power.—252. First creation of organised beings.—253. General view of the series of catastrophes.—254. **The Palæozoic age:** Murchison's section of the corresponding stages.—255. How these are manifested in different parts of the world.—256. Stratigraphical evidence of the distinction of the stages.—257. Five stages of the Palæozoic formation.—258. Vegetable kingdom of the Palæozoic age.—259. First Palæozoic period.—260. Extent and limits of the seas.—261. Character of the Fauna.—262. Of the Flora.—263. Tropical climate universal.—264. No terrestrial animals.—265. Inhabitants of the seas.—266. Synopsis of the animal kingdom.—267. Examples —268. Duration of this period.—269. Second Palæozoic Period.—270. Synopsis of the animal kingdom.—271. Genera created and revived.—272. General character of the animal and vegetable kingdoms.—273. Outlines of land and water.—274. Elie de Beaumont's Silurian map of Western Europe.—Third Palæozoic Period: 275. Mineral character of the strata.—276. Table of the Fauna.—277. Mollusca and Radiata.—278. Outlines of land and water.—279. Extent of the seas.—Fourth Palæozoic Period: 280. Table of the fauna.—281. Fossil crustacea.—282. Mollusca and Radiata.

246. Since the technical names of several of the classes into which the principal divisions are resolved will not be familiar to some of the readers of this tract, it may be useful to indicate the origins from which they are severally derived.

Mammifers is from a Latin word, signifying the bearers of breasts or paps, and consequently is applicable to animals which suckle their young.

Reptile comes from the Latin word *repto*, I creep or crawl.

Insects are so called from a Latin word, signifying the division of its body into segments.

Myriapods is a Greek word, signifying thousands of feet, figs. 133, 134.

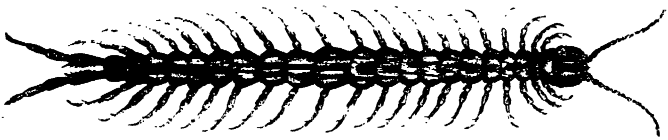


Fig. 133.—The Scolopendra.—Example of the class Myriapods.

Arachnida is taken from a Greek word, (ἀράχνη, arachné,) signifying a spider's web.

Crustacea is taken from a Latin word (*crusta*), signifying a hard covering or crust.

Cirrhipeds, or Cirrhopods as it is sometimes written, take their

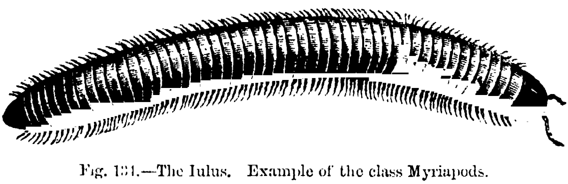


Fig. 134.—The Iulus. Example of the class Myriapods.

name from a Latin word (*cirrhus*), signifying hair, the compound signifying hair-footed animals; that is, whose members of locomotion are hairs, fig. 135.

Annelides, as well as Annulata, is taken from a Latin word (*annulus*), signifying a *ring*.

Cephalopods is a Greek compound, signifying *head-footed*, or animals whose organs of locomotion are upon their heads, figs. 9, 10, 11.

Gastropods is likewise a Greek compound, signifying *belly-*

footed, or animals whose organs of locomotion are attached to their bellies.

Lamellibranchia is compounded of two Latin words, (*lamella*, a

Fig. 135.—The Anatifa (animals which attach themselves to ships' bottoms). Example of the class Cirrhipeds.

plate or *leaf*; and *branchia*, a *gill*,) the class including those animals which have gills or branchia placed by pairs along the body, of a lamellated form.

Acephala is also a Greek compound, signifying *absence of head*.

Brachiopods is a Greek compound, signifying *arm-footed*, or animals whose members of prehension are also those of locomotion, figs. 18, 19, § 71.

Bryozoa, from the Greek word *βρύον*, a mossy sea-weed, figs. 20 to 23, § 73.

Echinodermata is a Greek compound, signifying *spiny-skinned*, fig. 136.

Polyparia is another Greek compound, signifying produced by polypes or corals, fig. 137.

Foraminifera is a Latin compound, implying the existence of foramina, or openings in the partitions of the shells, figs. 100 to 106.

Amorphozoa is a Greek compound, signifying living things *destitute of definite form*, figs. 138, 139, 140.

Infusoria is a Latin name, implying the existence of this class of animals in vegetable and other infusions, fig. 107.

247. Since many of the names of the genera and species of animals and plants would be unintelligible to a large portion of

Fig. 136.—The Holothuria. Example of the class Echinodermata.

our readers, while a full explanation of them would be incompatible with the objects and limits of the present tract, we shall generally adopt the expedient of giving a specific example of each

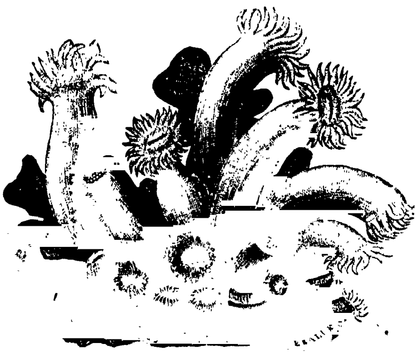


Fig. 137.—Polypes of the genus Asteroides. Example of the class Polyparia.

in a parenthesis after its technical name. In many cases, however, even this mode of illustration is not possible, since none of the species or genera of certain orders are familiar objects, and in many cases those which we shall have to mention have ceased to

exist, so that no analogous example can be found among the living classes. In such cases we shall endeavour, as often as convenient, to accompany the technical name with a figured

Fig. 138.

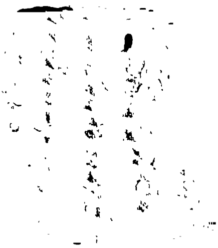


Fig. 139.

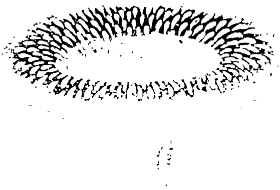


Fig. 140.

Examples of Amorphozoa.
Fig. 138.—Cliona Duvernoyi (fossil). Fig. 139.—Cribrospongia reticulata. Fig. 140.—A part magnified.

representation of some species of the object. In the preceding table we have accordingly given some familiar examples, and we now annex figured illustrations of those objects which may be supposed to be the least familiar to ordinary readers. The references to the figures are given in the table.*

248. Geologists have ascertained the existence of the organic remains of about twenty-four thousand species of the different orders of animals, which they have assigned to upwards of fourteen hundred and seventy genera. Of these numerous species none survive; but we find in the existing animal kingdom about five hundred and fifty of the genera, the remainder being extinct.

249. Until very recently, it was considered by geologists that those twenty-four thousand fossil species were distributed through the strata of the crust of the earth, in such a manner that the great majority of them should be common to strata of very different dates of deposition, and that comparatively few were exclusively found in strata of a particular date; these few being consequently called *characteristic species*, inasmuch as they supplied to geologists certain tests, by which the dates of strata left uncertain from their mineralogical character could be fixed. The elaborate researches of M. D'Orbigny, who has catalogued,

* We must warn the reader that he must not understand that the example given in the parenthesis is in every case an individual of the species, or even of the genus, of the object to be illustrated. It will be more generally a specimen of the class or order. This is the only expedient that I can devise to popularise this part of our subject.

described, and located on the earth's crust, above eighteen thousand species of Mollusca and Radiata alone, have demonstrated that all the species found in strata of the same date, with extremely rare exceptions, are characteristic of these strata, being found there exclusively, and in no other strata of anterior or posterior deposition; so that, instead of a few species only being characteristic, it would appear that all the species are so, with exceptions so rare as to be altogether insignificant.

It appears, therefore, that on the crust of the earth there is a sort of organic stratification, consisting of a series of superposed layers of animal remains, each of which contains a distinct collection of species, no two such layers having any species in common, save in very rare and exceptional cases, and that even these exceptions may be satisfactorily explained as arising from accidental causes.

250. Since twenty-nine such organic stages have been determined, it must be inferred that during the geological period corresponding to each of them, the earth was peopled by a collection of animals which had no previous or subsequent existence, and which constituted a distinct and independent creation. This inference is fully confirmed by the fact, that on comparing stage with stage, we do not find the successive faunas passing one into the other by slow and imperceptible degrees; but, on the contrary, we find between those of every two successive stages, a distinct and unmistakeable line of separation. In the superior layers of each stage, the fauna peculiar to it totally disappears, as though it were annihilated by some universally destructive agency; and it is not until we arrive at the lowest or first layer of the succeeding stage, that the next fauna appears not gradually and successively, but suddenly and simultaneously over the whole extent of the globe, so far as geological observation has extended, and everywhere, from the equator to the poles, the same species are found in it.

251. Hereupon two questions necessarily arise: What are the physical causes which produced the total destruction of the fauna of the inferior stage, and the creation of that of the superior? To the former a satisfactory answer is obtained, as we shall presently show, by the geological convulsions, the devastating effects of which have been already frequently noticed in these pages. But when we seek the agency which twenty-nine times successively called into existence a new animal kingdom to replace that which was previously destroyed, we are compelled to acknowledge the limits of our intellectual powers, and to prostrate ourselves in reverence before that Omnipotence to whose agency alone these great creative acts can be assigned. There are limits which the human

mind cannot overleap, circumstances before which the march of intellectual research must be arrested, and ultimate facts which must be admitted without any human power of explaining them.

252. When the temperature of the earth had cooled down to a point compatible with the maintenance of organised life, and its crust had thickened so as to give it comparative stability and permanence, it pleased the Omnipotent to call into existence the animal and vegetable kingdom, that continued to live upon the earth during the Cambrian period, and was destroyed by the convulsion which closed that period, the remains of the species composing it being deposited in its strata.

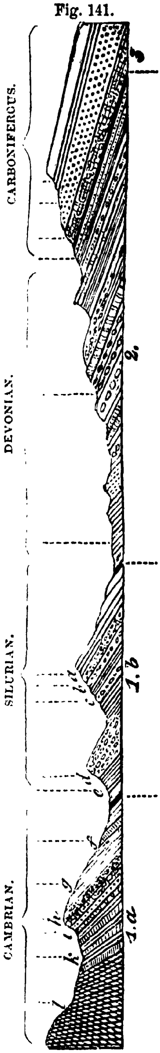
253. After this complete destruction of animal and vegetable life a period of repose ensued, after which the same Almighty Power at the commencement of the second Palæozoic or Silurian period, called into existence another and different animal kingdom; different, at least, so far as regarded species, many of the genera being common to that of the previous period. The close of the Silurian period was signalised by a like catastrophe, this second animal kingdom being similarly swept away and the earth again left unpeopled and destitute of vegetation. Another period of repose ensued, after which, at the commencement of the third Palæozoic or Devonian period, a third animal and vegetable kingdom was called into existence, and continued upon the earth during the Devonian period, at the close of which, in like manner, another destruction ensued, followed by another creation at the commencement of the fourth Palæozoic or Carboniferous period, and so on destruction following destruction, and creation following creation, during all the succeeding periods to that which immediately preceded the human epoch. The latest or fifth Tertiary period terminated like the others in a convulsion which swept from the earth all animal and vegetable life existing upon it, burying the remains in the highest layers of its crust. After a final period of repose, the present animal kingdom, including the human race, were called into existence, and the world as we see it commenced.

The Palæozoic Age.

254. The Palæozoic formation, whether it be examined in reference to its mineralogical strata or the organic remains deposited in it, is resolved into five distinct stages. The researches of Murchison in England and Russia, those of M. D'Orbigny in South America, those of several eminent geologists in the United States, and the observations of M. de Verneuil in France, all concur in establishing this division.

The stratification from the superior limit of the Azoic rocks upon which the Palæozoic formation rests, to the upper limit of the Carboniferous stage, delineated in section by Sir R. Murchison, is shown in fig. 141, as it is presented on the surface of the earth in strata variously inclined. The five divisions into which the whole formation is resolved are denominated, proceeding from the lowest upwards, the Cambrian (sometimes called the Lower Silurian), the Silurian, the Devonian, the Carboniferous, and the Permian.

Fig. 141.



255. In the geological map of England by Sir R. Murchison, the stages succeed each other regularly throughout Wales and the western parts of England, where they appear in some places in concordant, and in others in discordant, stratification. They are traced scarcely less distinctly in Germany. The same regular succession of five superposed stages is seen in Russia and in Sweden from west to east, and extending in the same order to Central Russia. Along the slopes of the Ural, the stages being tilted upwards, are found, as may be expected, in a contrary order, the lowest being the most eastward, and the uppermost the most westward. M. D'Orbigny found the same regularity in South America.

256. The complete distinction of the stages, and the geological evidence of the convulsions by which they were rendered separate and independent, are found in the fact that in some places particular stages are absent. Thus we see in the United States the three first stages only existing in concordant stratification for hundreds of leagues, the lowest being absent. The same is observable in the department of Sarthe and the Manche in France. Elsewhere the Carboniferous and Devonian stages alone are found; as, for example, in the Pas de Calais, and in certain parts of Spain, or one only of them, as in Norway, Sweden, Russia, France, and some other countries.

257. Upon a general view of the Palæozoic formation and its component stages, there is evidence, founded on the indications which

have been already explained, that during each of the five successive periods the earth consisted, as at present, of continents and seas; that the continents were clothed with vegetation; that the seas were peopled by various marine tribes, some living at parts of great depth, some near the coasts, and others upon the shores between high and low water-mark; and that even the crust of the earth was subject to the same gradual oscillations which are observed to exist at present in the north of Europe and in other parts of the globe.

258. The existence of a vegetable kingdom in each of the five Palæozoic periods is proved by the presence of coal in all the stages. That mineral is worked in Portugal in the Silurian stage. In Spain its richest mines are in the Devonian stage, and in Saxony it is worked in the Permian stage. These facts show, that though the coal-fields are by far most prevalent in the Carboniferous, the other Palæozoic stages furnish their share of that mineral to industry and the arts.

Having thus taken a general view of the Palæozoic age, considering its periods collectively, we shall now briefly notice the most remarkable circumstances attending these periods severally.

FIRST PALÆOZOIC PERIOD.

259. The first Palæozoic stage includes the group of strata of which the Cambrian system of Sedgwick and the lower Silurian system of Murchison are composed. It appears from an examination of the strata, more especially those observed in North and South America and Bohemia, that a considerable time must have elapsed between the epoch at which this stage began to be deposited on the subjacent Azoic rocks, and the commencement of the animalisation of the globe. Strata of immense thickness are everywhere found between the superior surface of the Azoic rocks and the first layers of organic remains, the formation of which, according to all the known laws of sedimentary deposits, must have occupied a great lapse of time. That these were deposited from waters which had a temperature too elevated to allow of organic life, is in the highest degree probable; and it must be inferred that the creation of an animal and vegetable kingdom, or a fauna and flora, as they are called, was postponed until the temperature of the globe had fallen to a point not much above that of the present tropics.

260. During this first Palæozoic or Cambrian period the waters of the ocean covered all that part of Europe extending from Spain to the Ural mountains, as well as a great part of North and South America. The shores of these seas can be traced, by the

means already explained, in the strata of England, Sweden, and Russia, and in those of the State of New York. The organic deposits show that, like the present seas, they were inhabited by the various classes of marine animals which are peculiar, some to shores within the play of the tides, others to littoral regions more removed, and others to the great depths of the ocean.

261. The only Vertebrate animals of this period which have left their traces are some placoid fishes, which belong to the family of Cestracions, of which the shark presents a living example. Of articulated animals there lived a great number of Trilobites (fig. 6, § 62), an order which at a period a little later became extinct. The forms of life, however, which most abounded belonged to the Molluscous and Radiated divisions. Tentaculiferous cephalopods swarmed in the seas, the genera of some of which did not survive the period, and those of many disappeared before the close of the Palæozoic age.

Molluscous brachiopods, marine gastropods, lamellibranchia (oyster and mussel), and bryozoa, existed in numbers more or less considerable.

Of the Radiata there prevailed echinodermata, asteroids, and numerous crinoids, a great number of polyparia or zoophytes, and some amorphozoa.

262. The remains of vegetation consist chiefly of some marine plants peculiar to the State of New York, described and figured by Mr. Hall. Coal of this epoch, which can only consist of vegetable remains, is worked at Vallongo in Portugal.

The remains of vegetation, as well as the visual organs of animals, show that light and air existed then as now. We have already noticed the structure of the eyes of Trilobites, and shown their analogy to those of insects and other Annulata.

263. It is certain, that not only at this first period, but at all succeeding periods, until that which immediately preceded the present creation, the heat proceeding from the interior predominated over the influence of solar radiation, in a sufficient degree to efface all isothermal lines, and to equalise the climate at all latitudes from the equator to the poles. Proofs of this will appear in the analysis of the fauna and flora of all the stages, since the same tropical genera and families will be found deposited in the strata at the line and within the polar circle, as well as at all intermediate latitudes.

264. In this first period no terrestrial animals existed, although the land was clothed with a luxurious vegetation; at least no remains of such are found. The perishable nature of the insects, and many other Annulata, might have caused their disappearance; but, notwithstanding this, traces of such tribes are found in later

deposits, and it is probable that if land Vertebrates had existed, remains of them would be found.

265. The seas, however, abounded with life, including animals of all the principal divisions, Vertebrata, Annulata, Mollusca, and Radiata.

In the following table we have given the genera of the animal kingdom during this period, exclusive of the Annulata.

266. *Synopsis of the Animal Kingdom (exclusive of the Annulata) in the First Palæozoic Period.*

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	1	1			
Mollusca.	Cephalopods	12	12	0	2	2
	Gastropods	12	12	0	0	0
	Lamellibranchia	11	11	0	1	1
	Brachiopods	14	14	0	4	4
	Bryozoa	8	8	0	3	3
Radiata.	Echinodermata	11	11	0	5	5
	Polyparia	7	7	0	3	3
	Foraminifera	0	0	0	0	0
	Amorphozoa	2	2	0	1	1
		78	78	0	19	19

267. Eighteen genera of Trilobites existed in the first Palæozoic period, of which seven never re-appeared in any future period, and are consequently characteristic of the Cambrian stage. Some individual examples of other Annulata have been found, one of the most remarkable of which is the Nereites Cambriensis, fig. 5, § 36. The number of species of the Mollusca and Radiata alone, exclusive of the other divisions, which are ascertained to have lived in this period, is 426. These have been catalogued and described by M. d'Orbigny.*

268. The duration of this first world of animal and vegetable life may be estimated with some degree of approximation by the thickness of the deposits produced in its seas, which has been found in many places so much as 13000 feet.

Its close is marked by the discordances of stratification which prevail between the Cambrian and the Silurian strata, and it is probable that the convulsion by which it was terminated, was that which raised the Morbihan system of mountains of M. Elie de Beaumont (208).

* Prodrome de Paléontologie, vol. i. p. 1—26.

SECOND PALÆOZOIC PERIOD.

269. The convulsion which closed the preceding period was succeeded by an interval of tranquillity of greater or less duration; after which, it pleased the Omnipotent, by a second great act of creation, to clothe the land with vegetation, and re-people the earth.

270. In the following table we have given, as in the former case, a synopsis of the generic forms of this new creation.

Synopsis of the Animal Kingdom (exclusive of the Annulata) in the Second Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	8	7	1	0	0
Mollusca.	Cephalopods	11	2	9	3	0
	Gastropods	10	2	8	0	0
	Lamellibranchia	8	2	6	0	0
	Brachiopods	17	7	10	1	0
	Bryozoa	10	5	5	1	1
Radiata.	Echinodermata	15	12	3	8	6
	Polyparia	20	16	4	3	3
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	0	1	0	0
		100	53	47	16	10

As before, the only important traces of the Annulata of this period which remain, are the Trilobites, of which nineteen genera have been found. Of these, eleven are identical with genera which existed in the previous period, and eight are new.

The total number of species of Mollusca and Radiata which have been ascertained to have existed in this period is 418, which have been described and catalogued.*

271. The only class of Vertebrates yet created were fishes, of which eight genera existed in this period, all of the placoid family (shark). One of these had existed in the previous period, the other seven being new.

272. The remains of the vegetation consist of some genera of marine plants, found in the state of New York, and figured by Mr. Hall. That the continents generally were covered with vegetation is proved by the traces of coal found in this stage at St. Sauveur. As in the former period, the animal remains are analogous to

* Prodrome, p. 27—35.

those of the tropics at present, and were uniformly distributed over all latitudes to which geological observations have been extended, from the line to latitude 69°, from which it is inferred, that during this period the temperature of the earth was everywhere tropical, and everywhere uniform.

273. The outlines of land and water were not materially different from those of the first period. It is probable, however, that the seas retired from a portion of the central part of Brittany, and advanced eastward, as well in Wales as in Cumberland, leaving in the west a larger portion of uncovered land. They extended, probably without interruption, from Europe to America, covered a great part of North and South America, as well as all that part of Europe which extended from Spain to the line of direction now occupied by the Ural mountains.

274. An examination of the Silurian strata has enabled M. Elie de Beaumont to trace an approximate sketch of the outlines of land and water in Western Europe, from which the map given in fig. 142 was drawn.

It appears from this, that there existed at this time two granitic tracts, one between Brest and St. Malo, and the other between Brest and Poitiers; the former having the direction of the Finistère, and the latter of the Morbihan system, a neck of land connecting them having the direction of the Longmynd system. These probably, therefore, owed their elevation to the three convulsions which produced these ranges severally. Other tracts of land existed in Cornwall, in Scotland, and in Sweden, as shown in the map, having the direction of the systems of Finistère and Longmynd. The granitic plateaux which include the Limousin and Auvergne were also then above the waters, and were connected with a much larger tract, extending from Toulon to Innspruck. This second Palæozoic period appears to have been terminated by the effects of the geological disruption which produced the Hundsruck system of M. Elie de Beaumont (209).

THIRD PALÆOZOIC PERIOD.

275. After an interval of tranquillity as before—the land being divided from the waters—the earth was repeopled with new tribes and clothed with new vegetation. The strata deposited during this third palæozoic period have been denominated by Sir R. Murchison, Devonian, from the circumstance of their prevalence in that county. The principal mineralogical characteristic of the Devonian stage is the old red sandstone.

276. The animal world, now called into life, consisted, so far as

appears by its organic remains of 156 genera (exclusive of the Annulata), of which 75 were new and 81 revived, having existed in the former periods. It appears from the following table that in this period the vertebrate animals were still limited to fishes, but their number was considerably increased, having consisted of only 8 genera in the preceding period, and of 26 in the present. This period was also signalised by the first appearance of reptiles, of which, however, one genus only, called the *Sauropterus*, was

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Third Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	1	0	0	0
	Fishes	26	26	0	13	13
Mollusca.	Cephalopods	13	5	8	6	2
	Gastropods	22	9	13	1	0
	Lamellibranchia	18	7	11	0	0
	Brachiopods	20	3	17	4	2
	Bryozoa	10	4	6	3	2
Radiata.	Echinodermata	18	11	7	22	8
	Polyparia	26	8	18	10	5
	Foraminifera	0	0	0	0	0
	Amorphozoa	2	1	1	0	0
		156	75	81	59	32

created, being a large marine animal. Among the Annulata some genera of Tubicolous Annelidans appeared—so called from having lived in tubes. Among the crustacea as before, were some genera of Trilobites, but the period took its prominent character from the vast numbers of cephalopods, gastropods, lamellibranchia, brachiopods, crinoids, and polyparia, which swarmed in the seas.

277. The total number of species of mollusca and radiata alone, which existed in this period, as ascertained by the organic remains deposited in the stage, was 1198. These have been catalogued and described.*

The seas nourished marine plants, the discovery of many of which is due to Mr. Hall, of the United States. The continents were covered with a luxuriant vegetation, as appears from the rich deposits of coal found in the great basin of Sabero in Spain, which were long considered to have belonged to the succeeding period. The uniformity of temperature over the whole surface of

* Prodrome d'Orbigny, 52—109.

the globe, is proved by the existence of the same animal and vegetable remains in this stage, in all localities to which geological researches have been extended.

278. The configuration of land and water in this period has been determined on the principles already explained. The Hundsruck system of Elie de Beaumont, directed W. 31° S., having raised up the Silurian stage, increased the magnitude of the islands which existed in the previous period, created new ones, and gave to their coast its own prevailing direction. This will appear by reference to the map (fig. 144) sketched by M. Elie de Beaumont, showing the probable outlines of land and sea in Western Europe in the succeeding period. A tract of land arose above the waters on the west of Frankfort, and another on the S.W. of Strasbourg, which was united with the former continent. The central plateau of France was extended to the Pyrenees. The space included between the two islands of Brittany, which previously existed, was now filled up, and being united with the land round Cherbourg formed one continuous tract, which was connected on the one side with the southern part of England, and on the other with the Limousin by Poitiers. The land constituting the Scandinavian peninsula was also considerably increased. Upon several parts of this tract the Silurian deposits have never been since disturbed.

279. The seas of this period covered Asia Minor, Spain, Belgium, Germany, and Russia, as far as the Ural chain. The land which now forms the shores of the Frozen Ocean was also covered by these seas. In the east they extended from Asia Minor to China; in South America they covered all the tropical regions of Peru, Bolivia, and Brazil, and probably extended as far as the Falkland Islands, as is proved by the organic deposits found in all these regions. In North America they covered all the land which extends from Alabama to the state of New York. They also covered New Holland and Van Diemen's Land. Thus it appears that the Devonian sea extended in the Southern Hemisphere to 52° of latitude, and in the northern to the polar circle.

FOURTH PALÆOZOIC PERIOD.

280. The convulsion which terminated the previous period destroyed 59 generic animal forms, which never again reappeared upon the earth, as well as 1198 species of Mollusca and Radiata, besides all the species of the other classes. After an interval of tranquillity the earth was again repeopled, and once more clothed with rich vegetation. The new animal kingdom called into

existence is shown in the following table, exclusive as before of the Annulata.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fourth Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	1	1	0	1	1
	Fishes	46	33	13	37	27
Mollusca.	Cephalopods . .	11	3	8	6	2
	Gastropods . .	26	6	20	6	1
	Lamellibranchia	19	4	15	4	1
	Brachiopods . .	13	0	13	2	0
	Bryozoa . . .	14	6	8	5	5
Radiata.	Echinodermata .	18	11	7	17	10
	Polyparia . . .	20	6	14	19	6
	Foraminifera .	1	1	0	1	1
	Amorphozoa . .	1	0	1	0	0
		170	71	99	98	54

281. It appears that of former genera 99 were revived, while 71 new ones were created, making the total number of genera then existing on the earth 170. Besides these, however, there were at least 3 genera of Crustacea. This period was also signalised by the first unequivocal appearance of insects and Arachnida (scorpions) (fig. 143), the organic remains including besides Arachnida three orders of insects—the Coleoptera (beetles), the Orthoptera (crickets, locusts, grasshoppers), and the Neuroptera (dragon-flies).

282. Exclusive of the remains of animals of the other divisions, the number of species of Mollusca and Radiata alone ascertained to exist in this period, is 1047, which have been catalogued and described by M. D'Orbigny.*

* Prodrome, p. 110—162.

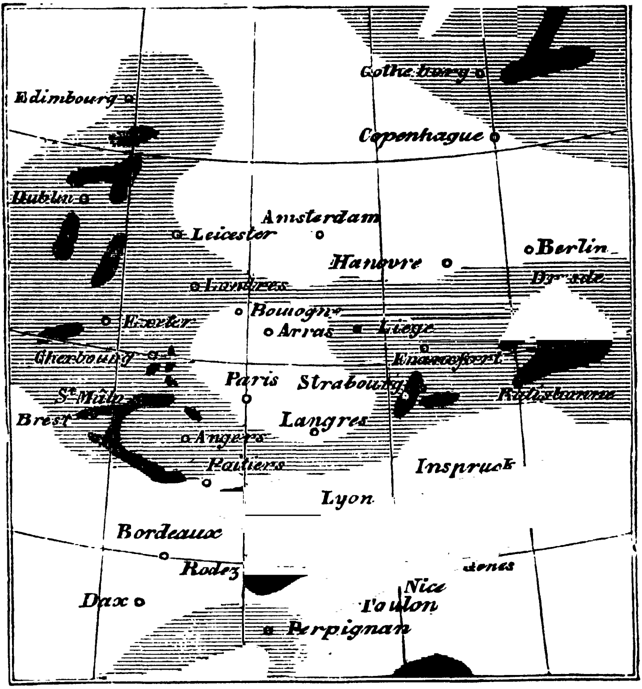


Fig. 142.—Configuration and relative extent of land and water in Western Europe during the Silurian period. *

THE PRE-ADAMITE EARTH.

CHAPTER IV.

283. Outlines of land and water.—284. The vegetable kingdom.—285. Coal deposits.—286. Convulsions which terminated the period.—FIFTH PALÆOZOIC PERIOD: 287. Composition of the strata—288. Destruction of the fauna and flora of preceding period.—289. The new animal kingdom.—290. Outlines of land and water.—291.

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* The dark parts are supposed to represent land. This map is reproduced, with the permission of the author and publisher, from the Traité de Géologie of M. Beudant.

Changes of the continents.—292. Character of the fauna.—293. Absence of land animals—uniformity of climate.—294. Geological convulsions.—RETROSPECT AND RECAPITULATION OF THE PALÆOZOIC AGE : 295. Commencement of animalisation.—296. Prevailing forms. —297. Trilobites.—298. Characteristics of the carboniferous stage. —299. Carbonised vegetables.—300. Fossil vegetable species.—301. Their prevailing characters.—302. Contrasted with the present vegetable kingdom in the same localities.—303. Radiata of the carboniferous period.—304. Crustacea and insects.—305. Fossil scorpions. —306. Fishes of the carboniferous period.—307. Fossil fishes discovered by M. Agassiz. **Triassic Age.**—308. Triassic formation lies over the Palæozoic.—309. Geographical configuration—Map of France in Triassic age.—310. Vegetation. FIRST TRIASSIC PERIOD : 311. Outlines of land and water—character of animal kingdom.— 312. Chelonian reptiles (tortoises).—313. Foot-tracks of birds.— 314. Synopsis of animal kingdom. SECOND TRIASSIC PERIOD : 315. Mineral character of this stage—animal genera created and revived. —316. Outlines of land and water—animal kingdom.—317. Generic synopsis.

283. THE convulsions which produced M. Elie de Beaumont's system of the Ballons, pushed up certain parts of the Devonian stage, modifying the outlines of land and water, and augmenting the extent of the land. The map (fig. 144) represents approximatively the seas and lakes of this period as they existed in Western Europe.

284. Arborescent ferns, with their beautiful lace-like foliage; slender Lepidodendrons, fig. 145; Lycopodiaceæ (club-mosses), with leaves as varied and beautiful as the ferns; and gigantic Sigillaria, emulating the magnitude of the Conifers, abounded.

Assuredly no scenery upon the earth at present can convey an adequate idea of vegetation so luxuriant. Some of the mountainous regions of the torrid zone may convey a faint notion of it; but at the period to which we now refer, this magnificent flora covered the whole surface of the land from the tropics to Melville Island, now the regions of eternal frost.

285. By a dispensation of Providence, which cannot fail to excite sentiments of admiration and gratitude, this luxuriant vegetation of a remote epoch of the earth, flourishing countless ages before the creation of the human race, was destined to become for that race one of the most powerful agents of industry and civilisation. Buried in the earth by a long series of geological convulsions, it was submitted to the process of carbonisation, and converted into those vast beds of mineral combustible which now supply the materials out of which art and science have educed not only the means of artificial light and heat, but also a mechanical agent whose influence upon the condition of mankind is incalculable. To these precious deposits of the carboniferous

period are, in short, due the physical agencies by which the art of gas illumination, all the industries depending on the production

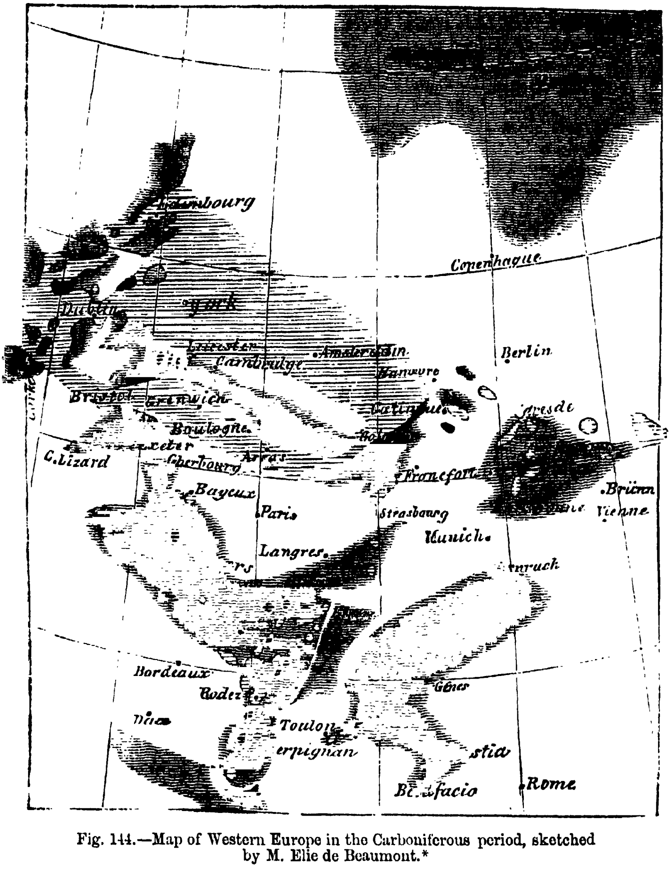

Fig. 144.—Map of Western Europe in the Carboniferous period, sketched by M. Elie de Beaumont.*

of artificial heat, and all the wonders effected by the steam-engine are due.

286. It is to the close of this fourth Palæozoic or Carboniferous period, and before the commencement of the Permian deposits,

* This map is reproduced from the Geology of M. Beudant, with the permission of the author and publisher.

that Sir R. Murchison assigns the date of the disruption of the earth's crust, which produced the Ural chain of mountains.

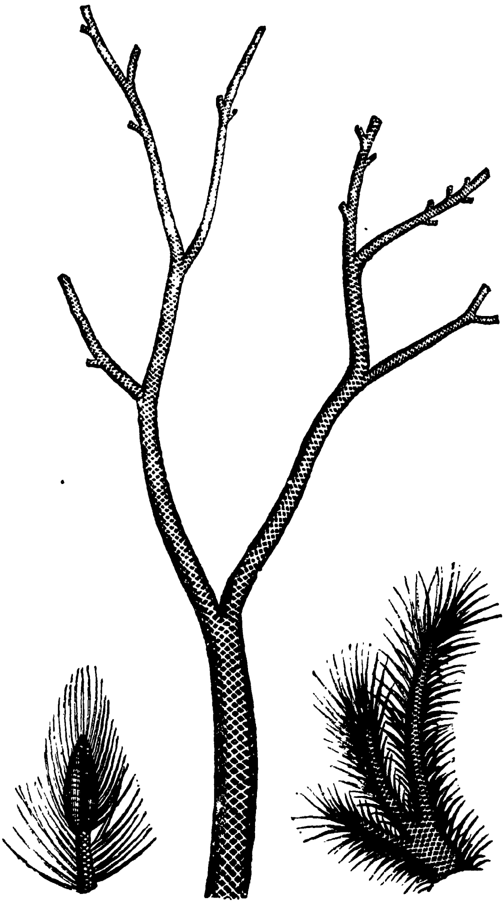

Fig. 145.—Lepidodendron Sternbergii.

M. Elie de Beaumont assigns to the same epoch the convulsions which produced the system which he has designated that of the North of England (211), the prevailing direction of which is

N. 5° W., and S. 5° E. M. d'Orbigny assigns to the same epoch the convulsion which produced the Chiquitean system of mountains in Bolivian Peru; and to the disturbance produced by one or all of these simultaneous convulsions, may be ascribed the destruction of the whole animal and vegetable kingdom which closed this fourth Palæozoic period.

FIFTH PALÆOZOIC PERIOD.

287. The strata which, in the regular series lie over the Carboniferous stage, have received the name of the Permian, from the Russian province of Perm, on the confines of Europe and Asia, which is traversed by the Ural mountains, this being the region in which the geological characteristics of this stage were first studied and determined by Sir R. Murchison. The component strata are commonly known to geologists as those of the magnesian limestone and new red sandstone, in contradistinction to the old red sandstone of the third Palæozoic or Devonian stage. That this stage has been separated from the carboniferous by a geological convulsion is rendered manifest by the discordance of the stratification in some places, and by the isolation of the stages in others, the Permian stage being found in some places without the Carboniferous under it, showing that it was there deposited in parts of the earth's surface which were dry land during the Carboniferous period.

288. The convulsion which terminated the Carboniferous period buried beneath its ruins nearly a hundred genera which never again appeared. Of the Mollusca and Radiata alone, exclusive of the other classes, 1047 species were destroyed by this catastrophe. All the vast forests which covered the extensive tracts of land were similarly buried, and form, as already explained, the coal-fields now found in the Carboniferous strata. This catastrophe was probably followed, as in the former case, by a period of tranquillity, during which a suspension of all animal and vegetable life took place. The seas, meanwhile, returning into their beds, the land was again divided from the waters, and the outlines of the new continents and islands became defined. The earth being thus gradually prepared, Omnipotence once more exerted its creative power, re-peopled the world, and clothed the land with vegetation.

289. The new animal kingdom, as far as its remains inform us, consisted of eleven new, and forty-five revived genera, making a total of fifty-six. Two of these belonged to the class of reptiles, twelve to that of fishes, and the remainder to the inferior divisions of the animal kingdom, as shown in the following

synoptical table—exclusive, however, of the Annulata, whose numbers cannot be so certainly ascertained.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fifth Palæozoic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	2	1	1	1	1
	Fishes	12	5	7	6	3
Mollusca.	Cephalopods	2	0	2	0	0
	Gastropods	5	0	5	1	0
	Lamellibranchia	13	3	10	0	0
	Brachiopods	11	0	11	3	0
	Bryozoa	8	1	7	4	1
Radiata.	Echinodermata	1	0	1	0	0
	Polyparia	2	1	1	2	1
	Foraminifera	0	0	0	0	0
	Amorphozoa	0	0	0	0	0
		56	11	45	17	6

290. The seas during this period covered most probably the space occupied by the chain of the Vosges mountains in Europe, extending in a direction nearly N.N.E., through Rhenish Bavaria and the Grand Duchy of Baden, into Saxony and Silesia. The identity of the species of organic remains found in these deposits in Silesia, England, and Russia, proves that the seas of this period which covered the central part of England, from Glamorganshire to Durham, communicated with those of Russia, where they extended in the direction N.N.W. between the Ural chain and Novogorod, from the 48° of latitude to the Frozen Ocean.

They also covered Tasmania, in the Southern Ocean; and probably, therefore, extended over the entire surface of the earth from the 43° of south to the 80° of north latitude.

In the western part of continental Europe the outlines of land and water did not undergo any remarkable change. The great central plateau of France formed a large island, which extended to the south as far as the Pyrenees, as is indicated by the terrestrial plants now found in the deposits of Lodève, in the department of Herault, in France. The remainder of continental Europe consisted chiefly of a tract of land in Brittany. In England, besides parts of Devonshire and Wales, which were previously raised above the level of the ocean, a vast island was formed, extending N. 5° W. and S. 5° E., consisting of land forced

above the Carboniferous seas, and surrounded east and west by the waters of the Permian seas.

291. The Ural chain was also further heaved upwards, so as to form the series of mountains which now exist. In South America the continents were also considerably increased in extent in the west. The Chiquitean chain extended over some hundred leagues, from Brazil to the eastern extremity of the Andes. South America appears then to have had the form of a vast triangle, the length of which, from north to south, extended over 35° of latitude.

While the land underwent but little change in France, it was enlarged both in England and Russia, towards the east, by a considerable portion of the Carboniferous stage not covered by the waters of the Permian sea.

292. The fauna of this period were almost exclusively marine, a few, perhaps, being fluviatile. The two genera of reptiles were both fluviatile and marine. The fishes belonged to the Placoid and Ganoid families, of which the shark and sturgeon are living examples. Among the Mollusca, certain species of oysters first appeared in this period.

293. Although the organic remains present no traces of land animals, it is nevertheless probable that they prevailed upon the continents at least as extensively as in the previous period. M. Brongniart considers the vegetable fossils of this period to hold an intermediate place between those of the previous and succeeding periods. The marine fauna found in the Old and New World from the line to the 80° of latitude being identical in its character, demonstrates that central heat still neutralised the effects of solar radiation, so as to efface all isothermal lines, and that over the entire globe a tropical climate prevailed.

294. This period, like the others, was tormented by geological convulsions, of which the traces are found in the discordance of the stratification and the increased elevation of the immense surface constituting the Permian formation in Russia, in the dislocation which produced the Netherland range of mountains and those of South Wales. The effects of these geological perturbations are altogether in accordance with the superior limits of the fauna and flora of the Permian stage.

RETROSPECT AND RECAPITULATION OF THE PALÆOZOIC AGE.

295. With the Permian period was closed the Palæozoic age. The first assemblage of animated beings which peopled the earth included types of all the principal divisions of animal forms, but those of the lowest class most abounded. Thus, three animal and vege-

table kingdoms were called successively into existence, permitted successively to live, and were destroyed successively before any vertebrate animals superior to fishes existed, and even these were limited to the Placoid and Ganoid orders. No land animals had yet appeared. Reptiles made their first appearance in the fourth period, where they were represented, however, only by a single genus; and even in the fifth and last period, no more than two genera existed, one of which had been revived from the preceding period. During the entire age, not more than sixty-seven genera of fishes existed, and two of reptiles. Of the superior orders of birds and mammifers none were yet created.

296. The animal forms which most abounded were those of Tentaculiferous Cephalopods, Marine Gastropods, and Lamellibranchia, Brachiopods, Bryozoa, Echinodermata, and Polyparia, commonly known as zoophytes. Of the divisions of Annulata in this age but little is known, owing, no doubt, to the perishable nature of their structure. One family, however, of Crustacea, Trilobites, appeared during the first and succeeding periods in such numbers, as to confer upon the epochs a distinct organic character. These fossils have been long known in England under the local and erroneous name of *Dudley insects* or *locusts*, from their having been found in that district in such immense numbers. This remarkable family of Crustaceans did not survive the fourth Palæozoic or Carboniferous period, their principal development being in the Silurian and Devonian periods, which literally teemed with them. These crustaceans have no existing type, that which most resembles them being the Bopyrus, a small parasitical animal which attaches itself to the prawn, causing a large swelling in its body.

297. The fossil trilobites are generally from one to six inches in length, attaining, nevertheless, in exceptional cases to two feet. They were protected by a crustaceous shell or case, composed of annular segments, jointed one upon the other like those of the lobster's tail. This testaceous covering seems to have had a contractile power like that of the armadillo, since the animal is sometimes found more or less expanded, and sometimes coiled up. Owing to the absence of all traces of antennæ or feet, it is supposed that these animals adhered to rocks like fuci, or collected together in masses, forming conglomerations. Some naturalists, however, assume that they had locomotive power in water, either by soft paddles which have disappeared, or by skulling forward by means of the flexible extremity of their bodies. From the peculiar structure of the mouth it has been inferred that they were carnivorous, preying on naked mollusca or annulata, with which their remains are sometimes associated.

The curious and interesting structure of the eyes of the trilobite have been already noticed (62).

298. The most striking and imposing feature of the fourth or Carboniferous period of the Palæozoic age, consists in the numerous accumulations of vegetable remains which are presented in the coal deposits in all parts of the world. As the science of Comparative Anatomy has enabled the geologist to reproduce the forms and determine the habits and functions of the animal tribes which peopled the earth at these remote periods—in like manner the principles of Botanical Science have enabled him, basing his conclusion upon the visible structure of vegetable remains found in the coal beds, to reproduce, as it were, the vast forests of palms and arborescent ferns, the groves of conifers, and all the exuberant vegetation which flourished during the second, third, and fourth Palæozoic periods.

299. The layers of pure coal consist altogether of carbonised vegetables; and when it is considered that these strata are sometimes sixty feet in thickness, it seems difficult to explain how an accumulation of wood, plants, and foliage could ever be produced in such enormous quantity. Though the vegetable remains are always in a carbonised state, the leaves often possess such tenacity as to be separable from the stone. These and the seed-vessels which are found in iron-stone, have in many cases undergone metallic impregnation, which has in no degree impaired the delicacy of their structure. The coal plants have been determined to the number of nearly a thousand species, two-thirds of which are related to the ferns and the higher tribes of Cryptogamia, the remainder consisting of conifers and some flowering monocotyledonous (having only one seed lobe), and dicotyledonous (having two seed lobes) trees; numerous species, however, are still undescribed, and new forms are continually discovered.

300. More than two hundred species of plants have been discovered in the British coal-mines, but far greater numbers are found in the Carboniferous deposits of Europe, America, Australia, and even Greenland; and it is worthy of note, that in the coal-field on the shores of Lake Breton, fossil plants have been discovered identical with those found in the coal-mines of Northumberland, though these deposits have been made in opposite sides of the earth.

301. The prominent character of the vegetable kingdom during the Carboniferous period was the immense predominance of the vascular and higher tribes of Cryptogamic plants, with which were associated in a much less number, palms, conifers, cicadeæ, and other plants approaching to the character of Cacteæ and Euphorbiaceæ. Plants analogous to the tribes of Ductulosæ

abounded, differing, however, both in genera and species from those which at present exist. Thus fossil Calamites, related to the equisetum or mare's-tail, are found, which measure eighteen inches in circumference and thirty or forty feet in height, while the recent analogous species seldom exceed an inch in diameter and two feet in height. The fossil arborescent ferns called Sigillaria, measure sometimes fifty feet in height, having their summits covered with a splendid canopy of foliage. The foliage of the herbaceous species is extremely elegant, presenting endless varieties in their forms and in the skeletons of their leaves. The fossil arborescent club-mosses, called Lepidodendra (from a Greek compound signifying scaly tree), attain frequently an elevation of from sixty to seventy feet. Some of these trees have been found entire from their roots to their topmost branches. Their foliage consisted of simple linear leaves, spirally arranged round the stem. These leaves, in many cases, had been shed from the tree, the marks of their points of attachment never having been obliterated. In their external forms, the mode of ramification and the disposition of their foliage, they closely resemble the existing Lycopodiaceæ, or club-mosses. Notwithstanding the enormous disparity of magnitude between these latter and the fossil Lepidodendra, Brongniart has shown that both belong to the same family. The fossils were in fact nothing more than arborescent Lycopodiaceæ, analogous in magnitude to the largest existing pines, and forming extensive forests during the Carboniferous period, beneath whose shade flourished the lesser ferns and associated plants now found with them in the same coal strata.

302. The contrast which such a flora presents with that afforded by the woods and forests which now grow on the surface of the carboniferous districts of England is as striking as the discrepancy between the zoology of the Palæozoic formation and that of the present day.

303. Among the Radiata of the Carboniferous period are enormous quantities of corals denominated, according to their several forms, tubipora, syringopora, catanepora, &c. Of the Echinodermata, crinoids swarmed in such infinite numbers that entire strata are composed of their petrified remains. These species have also received names indicative of their forms, such as actinocrinus, cyathocrinus, and so on.

Among the shells of the Carboniferous period are found innumerable Foraminifera, which are detected in slices of Yorkshire limestone with the microscope. The upper strata of the mountain limestone of the lower Volga in Russia consist of masses of a minute species of fusulina, resembling grains of wheat. Entire

beds of mountain limestone or conglomerates are formed of shells of Brachiopods, such as spirifers, leptænæ, &c.

304. The Crustacea and Insects of the Carboniferous period have been less accurately ascertained than the other divisions of the animal kingdom. A few species of the fluviatile crustaceans, the Cyprides, are found in the coal deposits. Small crustaceans are also found in the iron-stone, which are referable to the limulus or king-crab, a genus which abounds in the seas of India and America. Dr. Mantell found in the iron-stone of Colebrook Dale several fossil beetles resembling the curculio or diamond beetle; he also discovered the wing of a large neuropterous insect closely resembling a species of the living Corydalis of Carolina.

305. With the insects imbedded in the coal strata are found the remains of those animals, to which they served as food. The fossil scorpion (fig. 143) already mentioned is an example of this. This fossil, which measures about two and a half inches in length, is embedded in coal-shale, with leaves and fruit; the legs, claws, jaws and teeth, skin, hair, and even a portion of the trachea, or breathing apparatus, are severally preserved. It had twelve eyes, the sockets of which remain. One of the small eyes and the left large eye retain their forms, and have the cornea or outer skin preserved in a corrugated or shrivelled state. The hairy covering of the animal is also preserved, being neither carbonised nor decomposed; the substance of which it consists, electrine, has resisted decomposition and mineralisation.

306. Among the fishes which lived during the Carboniferous period, and which, as already stated, are exclusively of the Placoid and Ganoid families, some genera are worthy of note.

Of the Sauroid fishes, two genera, one called the Megalichthys, is covered with enamelled smooth quadrangular scales, very thick, and nearly an inch wide. The head is protected by strong armour of enamelled plates. The teeth are large striated hollow cones. This fish was from three to four feet in length.

Another called the Holoptychius, attained in some instances the length of thirty feet. The scales were thin and circular, varying from one to five inches in diameter. The head is surrounded with a sort of shagreen helmet, having a surface irregularly ridged. It has large teeth of great density, some conical and others long and slender.

307. M. Agassiz has discovered about a hundred species of fossil fishes of the Devonian and third Palæozoic period, of which the most remarkable are the Cephalaspis, Pterichthys, and Coccosteus.

The Cephalaspis—a Greek compound, signifying buckler-head—received its name from the head being protected by a buckler or shield. The plates which cover it are united in a single osseous

case. The body is covered with scales, those of the head being highly ornamented.

The Pterichthys takes its name from two wings or lateral appendages, which, like the spines of the common bull-head, were weapons of defence. The head and fore part of the body are protected by large angular escutcheons—two eyes are placed in front of the lateral spines. The species of these which occur in the British strata are from eight to ten inches in length, but specimens of still greater length were found in Russia by Sir R. Murchison.

Triassic Age.

308. Above the Palæozoic formation a group of strata has been deposited, called the Triassic formation (47), consisting of the new red sandstone, muschelkalk, and variegated marls, or marnes irisées of the French. This formation has been generally considered as consisting of three stages. A scrupulous analysis of its composition, as well with relation to its fossils as to the conditions of its stratification, shows that, between the sandstone and the muschelkalk, there is no real distinction either geological or zoological. We shall, therefore, here, following D'Orbigny, consider the Triassic formation as consisting of two stages only; the first, or lower, called the Conchiferous; and the second, or upper, the Saliferous, from the prevalence of salt-mines in it; such, for example, as those of Salins, Lons-le-Saulnier, and Salzbourg.

309. The configuration of the land in this, as in the former age, is traced by observing the outlines of the strata, and the distinction of their organic remains. The convulsion which elevated the system of the Rhine (213) produced a general deluge, which devastated the earth, destroying altogether the vegetation which clothed it, and the races which peopled it in the last period of the preceding age. When the seas had retired to their new beds, and tranquillity was re-established, the outlines of land and water were defined. A great island seems then to have extended from the west of England across France to Austria, including Brittany, the Limousin, and Forez, throwing out two peninsulas, one towards the Pyrenees, and the other across the province of Burgundy (fig. 146).

Another island coincided in position with Belgium, throwing out a peninsula to the south, which extended over the Vosges and the Grand Duchy of Baden, its direction being parallel to the range of the Black Forest. The land previously uncovered in England, extending from Cornwall through Wales to Cumberland, was probably increased by a large surface, extending from Derbyshire to Durham. With these exceptions, the land seems to have remained generally as it was in the Carboniferous and Permian

periods. Since the Permian stage in Russia is not overlaid by the Triassic, it follows that the Swedo-Russian continent, at the commencement of the Triassic age, extended over all northern Russia, from the Baltic to the Ural Mountains, and from the shores of the Frozen Ocean to the government of Saratov.

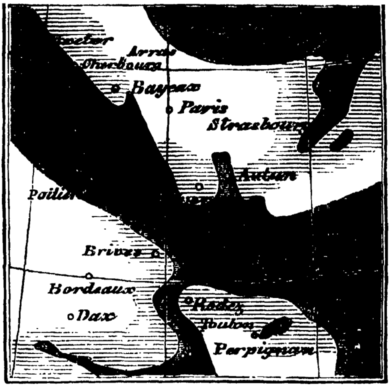

Fig. 146.—Map of France in the Triassic age.

310. A great change was produced in the character of the vegetation compared with that of the former periods. The arborescent ferns and tall equisetacean trees which prevailed in such lavish profusion in the latter periods of the Palæozoic age, now existed in greatly diminished numbers, while the conifers and plants, analogous to the zamias and the cycadeæ, figs. 147, 148, formed an important feature of the flora, preluding the immense development which these classes underwent in the succeeding periods.

FIRST TRIASSIC PERIOD.

311. By the catastrophe which terminated the Palæozoic age, ninety-one species of Mollusca and Radiata, besides all the existing species of the superior classes, were destroyed, never to re-appear upon the earth. Seventeen generic forms also became extinct. When tranquillity was re-established, and land and water again became fitted for the maintenance of organised life, Almighty Power called into existence thirty-six new generic animal forms, and revived thirty-three, which formerly lived, making a total number of sixty-nine genera in the new animal kingdom. Independently of the species of the higher classes of animals, not so exactly ascertained, the genera of Mollusca and Radiata alone consisted of 107 species,* which have been catalogued and described.

The marine littoral and fluviatile deposits have supplied the means of tracing the shores of the seas of this period, and prove them to have been subject to the same atmospheric and tidal influences as those which affect the seas and oceans of the present

* "Prodrome d'Orbigny," vol. i. pp. 171—178.

epoch. Among the remains of this period are eleven genera of saurian reptiles, of most singular forms, among which are included the Labyrinthodon, the restoration of which by Professor Owen is given in fig. 109.

312. Chelonian reptiles (tortoises) now appeared for the first time, together with six new genera of Ganoid fishes. Crustaceous decapods, as well as acetabuliferous cephalopods (fig. 149), also

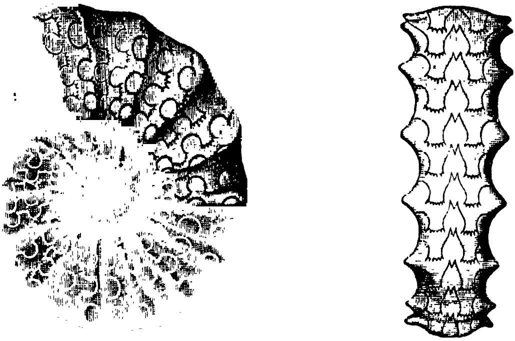

Fig. 149.—Ceratites nodosus (Fossil).

appeared for the first time, besides numerous lamellibranchia and echinoderms.

The Chelonians of this period are only known by the traces of their footsteps, which remain upon the rocks, figs. 108, 150.

Fig. 150.—Foot-print of the Chirotherium, a chelonian, or tortoise.

313. Numerous birds probably existed in this period; but, like

the chelonians, they have only left traces of their foot-prints (fig. 110). In fig. 151, are the imprints of the three fore phalanges of a

Fig. 151.—Foot-prints and marks of Rain-drops.

bird, accompanied by the curious incidental impressions of rain-drops which happened to fall at the moment the bird passed the spot.

314. *Synopsis of the Animal Kingdom (exclusive of the Annulata) during the First Triassic Period.*

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	?	?	?	?	?
	Reptiles	14	13	1	10	9
	Fishes	13	6	7	7	4
Mollusca.	Cephalopods	3	2	1	0	0
	Gastropods	9	2	7	0	0
	Lamellibranchia	17	5	12	0	0
	Brachiopods	3	0	3	0	0
	Bryozoa	2	1	1	1	0
Radiata.	Echinodermata	6	5	1	2	2
	Polyparia	1	1	0	0	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	1	0	0	0
		69	36	33	20	15

SECOND TRIASSIC PERIOD.

315. The mineral character of this stage has been variously denominated, red marl, keuper sandstone, and variegated marls.

The effects of the perturbation which closed the Conchiferous period are visible in the discordances of stratification, as well as by the marked distinction between the fauna and flora.

The termination of the Conchiferous period was marked by the destruction of all the existing species, animal and vegetable, of which there were 107 species of Mollusca and Radiata alone. With that period twenty genera ceased to exist (314). The next act of creation was signalised by the appearance of thirty-five new generic forms, and the revival of fifty-nine, which previously existed.

316. The outlines of land and water continued to be nearly the same, but the seas were peopled with tribes different from those of the preceding period. Three new genera of reptiles, all of which were probably fluviatile, appeared. The seas possessed two new genera of fishes and ammonites, and various other Mollusca were now first called into existence, giving a special character to the new fauna, which, with that of the first Triassic period, seems to constitute a transition system from the Palæozoic to the Jurassic age.

No remains of the terrestrial animals of this period have been found; but the land was certainly clothed with a luxuriant vegetation, of which numerous species have been preserved, as already mentioned, figs. 146, 147.

317. *Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Second Triassic Period.*

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	4	3	1	4	3
	Fishes	6	2	4	1	0
Mollusca.	Cephalopods . .	8	1	7	5	0
	Gastropods . .	20	4	16	2	0
	Lamellibranchia	22	5	17	1	0
	Brachiopods . .	7	0	7	4	0
	Bryozoa . . .	1	0	1	0	0
Radiata.	Echinodermata .	4	2	2	1	0
	Polyparia . . .	12	11	1	2	2
	Foraminifera .	0	0	0	0	0
	Amorphozoa . .	10	7	3	1	0
		94	35	59	21	5

Fig. 147.—Zamia pungens.

Fig. 148.—Cycas revoluta.

THE PRE-ADAMITE EARTH.

CHAPTER V.

318. Convulsion which closed the age. **Jurassic Age.**—319. Division of Jurassic formations into ten stages by M. D'Orbigny.—320. Nomenclature and thickness of the stages.—321. Section of the strata from the Vosges towards Paris.—322. State of the earth in the Jurassic age.—323. Jurassic age zoologically distinguished from the Triassic. —324. Distribution of the species into ten stages.—325. General inference respecting the distribution of specific forms.—326. Geography of Europe in Jurassic age—D'Orbigny's map.—327. The Anglo-Parisian basin.—328. The Pyrenean basin.—329. The Mediterranean basin.—330. Variation of the shores of these seas from period to period.—331. Discordances and isolation of the strata.—332. Corresponding observations on the organic deposits—333. Variations of the outlines of land during this age.—334. Change of condition of land between Toulon and Innspruck.—335. Accurate knowledge of the Jurassic geography.—336. Elie de Beaumont's Jurassic map.—337. Ichthyosaurus, Plesiosaurus, and Pterodactyle.—338. Other animals of the Jurassic age.—339. Coral reefs.—340. Insects.—341. The vegetable kingdom. First Jurassic Period. 342. Convulsion that closed the Triassic age.—343. First Jurassic stage determined by discordances and isolation of stratification.—344. Extent of the seas in Western Europe—remarkable discordances of stratification on the Alps.—345. Synopsis of the animal kingdom.—346. Reptiles, fishes and insects.—347. Convulsion which closed the period. Second Jurassic Period. 348. Mineral character of this stage.—349. Synopsis of animal kingdom.—350. Marine fauna.—351. No traces of terrestrial fauna.—352. Vegetation of the period.

318. THE close of the Triassic age is identified with the convulsion to which M. Elie de Beaumont ascribes the elevation of the Thuringerwald system of mountains, including the Bœhmerwald-Gebirge, and the Morven ranges, the prevailing direction of which is W. 40° N. and E. 40° S. M. D'Orbigny assigns to the same date and cause the increased elevation of all the eastern part of the Andes, included between the 5° and 20° lat. S., and having the direction W. 50° N. and E. 50° S. By combining with these dislocations the numerous discordances of stratification which are observed, we shall find causes abundantly adequate to the explanation of the total and sudden disappearance of the flora and fauna of the Triassic age, to give place to the new creations of the succeeding one.

The Jurassic Age.

319. Upon the Triassic formation the Jurassic has been deposited, and is therefore the result of the next geological age. Many divisions of the strata composing this great formation have been proposed, some based upon the mineralogical characters of the strata, derived, however, in general, from observations more or less local, and others from an imperfect generalisation of prevailing fossils. We shall here adopt the analysis of this formation proposed by M. D'Orbigny. "After many years of laborious observation," says that eminent palæontologist, "during which we have only advanced from confirmation to confirmation, without encountering any inconsistent facts, we have arrived at the conclusion that the Jurassic formation consists of ten stages, or superposed zones, limited and defined by their several fauna as distinctly as by their stratigraphical characters. In tracing them one after the other around various geological basins, we have ascertained that they are nowhere confounded, and that they represent clearly ten distinct epochs, one succeeding another in a constant and regular order. We have ascertained that the same succession takes place in the same order at all parts of the earth which have been submitted to exact observation, and that they are therefore the indications of the series of great geological phenomena which have been manifested during the Jurassic age." *

320. M. D'Orbigny has given to these ten stages names taken chiefly from the places, where their mineralogical characters have been most developed and observed. To avoid encumbering the reader with a nomenclature so complex, we shall here designate the stages according to their order of superposition, or what is the same, their dates of deposition, beginning from the lowermost

* D'Orbigny, Paléontologie, vol. ii. p. 419.

or earliest, and proceeding upwards to the uppermost or latest. It may, nevertheless, be useful to indicate the names given to them in the works of M. D'Orbigny and other French geologists, annexing the estimated average thickness of the stages.

Stage.	Name.	Origin.	Thickness. Feet.
X.	Portlandian	Portland oolite and limestone	200
IX.	Kimmeridgian	Kimmeridge clay	500
VIII.	Coralline	Coral rag	1000
VII.	Oxfordian	Oxford clay	500
VI.	Callovian	Kelloway's rock	500
V.	Bathonian	Bath oolite	200
IV.	Bajocian	Bayeux	200
III.	Toarcian	Thouars	500
II.	Liasian	Lias	500
I.	Sinemurian	Semur	1000
		Total thickness	5100

These approximate estimates of mean thickness are much below the real measures on the slopes of the Alps, the western declivity of the Vosges, and through all the series from Avallon to Tonnerre.

321. In fig. 152 is presented a section of the Triassic and Jurassic formations extending from the Vosges to Sommevoire (Haute Marne), directed towards Paris,* where the series of strata is complete, the successive stages of each formation being marked with the Roman numerals.

322. From an elaborate examination of the strata composing these ten stages in various countries and in different parts of the globe, it appears, that during the Jurassic age, the earth was subject to all the physical vicissitudes which are at present incidental to it. During each of the ten periods there were continents and oceans. As at present, peculiar classes of marine animals inhabited the coasts, the deeper littoral parts, and the still greater depths of the ocean. Then, as now, there were submarine currents, waveworn shores, sheltered gulfs and tranquil bays. The condition of the strata proves that during this age slow undulations of the crust, such as those which are now manifested in the Scandinavian peninsula (118), were frequent. This is especially manifested by the state of the strata composing the 3rd, 4th, 5th, 6th, and 7th stages, at Chaudon, in the department of the Basses Alpes in France.

323. The Jurassic age is distinguished zoologically from the Triassic age by the absence of forty-two genera, which became

* For the continuation of this section to Paris, see § 396 and § 456.

extinct in the latter, and from the succeeding ages of the world

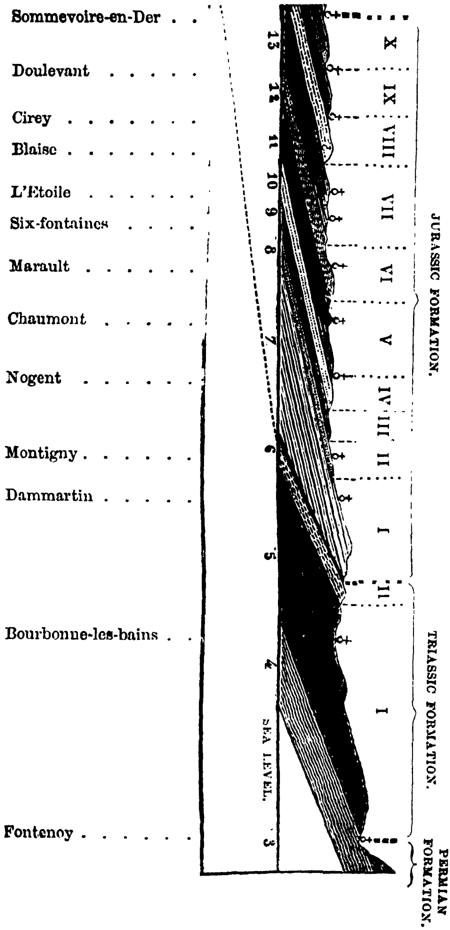

Fig. 152.—Section of the strata from the Vosges towards Paris.

by the absence of thirty-two orders of animals which had not yet appeared upon the earth, consisting of

	Orders.
Mammifers	11
Birds	6
Reptiles	2
Fishes	3
Crustacea	2
Insects	1
Mollusca and Radiata	7
	32

During this age nearly 300 new generic forms were called into existence, of which about 180 did not survive the age. This fauna consisted of about 4000 species, which were distributed among the ten periods, so that, save in very exceptional cases, no species are common to any two periods. Each period, therefore, had its own peculiar and characteristic animal kingdom.

324. To illustrate this remarkable principle, which seems to have been adhered to in all the operations of creative power from the first animalisation of the globe to the present period, we here subjoin a tabular synopsis, showing the number of species Mollusca and Radiata found in each of the ten stages, and also th number common to two or more stages.

Stages.	Species common to two or three stages.	Species limited to each stage.	Totals.
I.	1	173	174
II.	1	300	301
III.	0	288	288
IV.	7	596	603
V.	11	535	546
VI.	26	255	281
VII.	37	702	739
VIII.	27	628	655
IX.	16	183	199
X.	3	57	60
	129	3717	3846

But in the second column the same species is frequently repeated. Allowing for this, the total number of species which are found in more than one stage is only 56, or about 1½ per cent. of the entire number, a proportion which is altogether insignificant, and which cannot be considered as impairing the general law that each period had its own specific fauna.

325. From a general analysis of the facts, the following conclusions may be deduced:—

1st. That during the Jurassic age of the world about 4000 specific animal forms lived, different from any which existed at any antecedent or posterior epoch.

2nd. That this total number consisted of ten distinct groups,

which existed severally during the ten periods of the Jurassic age, their remains being deposited in the ten superposed stages which compose the Jurassic formation.

3rd. That each period, therefore, had its own special fauna, having nothing in common with the preceding or succeeding period.

4th. That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed $1\frac{1}{2}$ per cent. of the total number of species discovered.*

326. The geography of Europe in the Jurassic age has been traced and mapped with considerable precision by Messrs. Elie de Beaumont and D'Orbigny. The Jurassic formation, which has been well observed, and its limits determined, shows the extent and configuration of the seas, and consequently the outlines of the land. The Jurassic seas in Western Europe formed three principal basins, extending over certain parts of France and the eastern and southern parts of England. The form and limits of these are shown on the map (fig. 153), drawn by M. D'Orbigny, here reproduced with the permission of the author and publisher, which does not differ in any essential points from that of M. Elie de Beaumont (fig. 154), as will presently appear.

327. The Anglo-Parisian basin covering the north-west of France and the eastern division of England, was limited in England by a line directed N.N.E. from Somersetshire to Durham, passing therefore through the counties of Gloucester, Worcester, Stafford, Derby, and York; all that part of England to the east of this line being then covered by the sea.

On the other side of the Channel, the western shores of this basin passed across Normandy from St. Lo southwards to Angers on the Loire. It skirted the northern limit of the central plateau from Angoulême to Autun. On the north its shores were directed from Calais by Arras to Metz and Verdun, where they turned southwards to Chaumont. This basin communicated with the other two by two straits, one of which extended from La Rochelle to the eastern part of Angoulême, marked in the map as the Breton Strait, and the other from Chaumont to Autun, marked as the Belgi-Vosgian Strait. All that part of the channel east of Devonshire constituted part of this Anglo-Parisian basin or sea. The entire province of Brittany in France was at this epoch dry land.

328. The Pyrenean basin was limited on the north by the Breton Strait, and on the north-east by the central plateau,

* D'Orbigny, Paleontologie, vol. ii. p. 426.

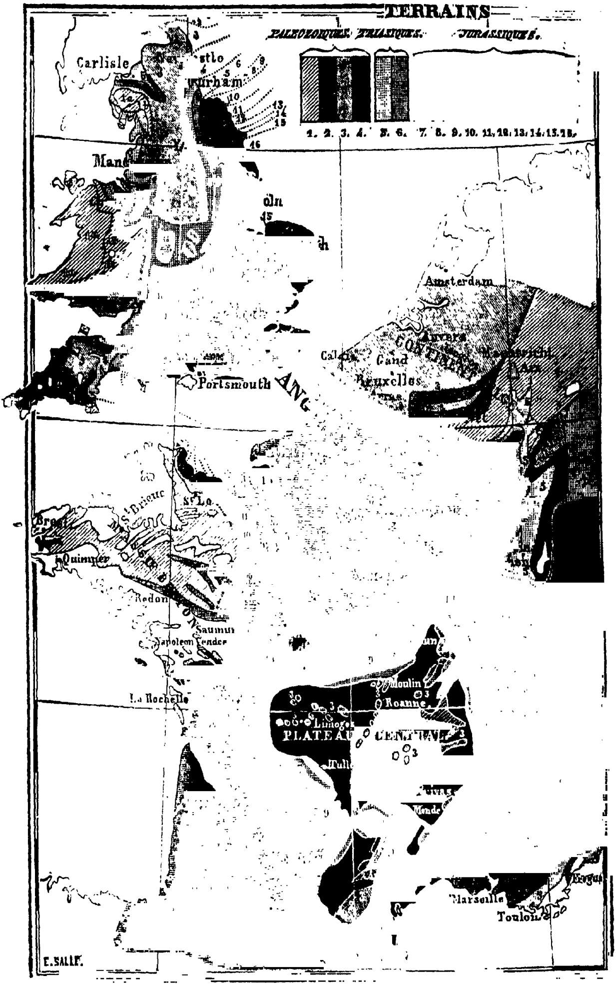

Fig. 153.*—Map showing the outlines of land and water in Western Europe in the Jurassic age. By M. D'Orbigny.

* In this map the dark shading, corresponding with the shades marked

which had been above the waters from the earliest geological dates. The southern limits of this basin are not so well ascertained, but it is certain that it covered all that part of southern Europe, from the surface of which the chain of the Pyrenees burst upwards at a later epoch, and extended far into the Spanish peninsula.

329. The third great European sea, called the Mediterranean basin, skirted the eastern side of the central plateau from the southern limit of the Vosgian Strait to Montpelier, where it was probably connected with the Pyrenean basin by another strait extending from Montpelier to Perpignan. This ancient sea extended in all probability to a considerable distance east and north-east, covering Provence and Dauphiné, all that part of Europe from which the chain of the Alps arose at a much later epoch, and all Piedmont, Switzerland, and Italy, with the exception of an island in the department of the Var in the south of France, which was already dry land in the preceding age, and continued so.

330. At each succeeding period of the Jurassic age, the shores of these seas retired from point to point within their preceding limits, so that their successive outlines formed a series of concentric lines, one included within the other, the seas retaining their form, but contracting their dimensions. This series of changes is especially remarkable in the case of the Anglo-Parisian basin, where it is indicated on the map (fig. 153) by the alternate shadings in two different tints around the borders of the basin. The limits during the first Jurassic period are those marked 7, the second 8, the third 9, and so on, the last or innermost being 16.

It appears, therefore, that each of the disturbances or dislocations, which terminated the successive periods, was attended with the effect of contracting the dimensions of these seas, either by the elevation of the surrounding land, or the depression of that which formed the bottom of the sea. The entire breadth of the zone of land, which being covered by the seas of the first Jurassic period was left uncovered by those of the last period of that age, is found to have been about a degree on the western declivity of the Vosges. It is a singular geological fact, that a succession of ten dislocations, each of which was sufficient to destroy the existing fauna and flora, should nevertheless leave unimpaired the general form of the seas, and that none of the more recent and more violent convulsions of the succeeding ages should have

7 to 14 inclusive, are to be understood as indicating water, and the other parts land.

effaced the traces, by which the outlines of the land and water during these successive periods have been determined.

331. It will be seen by reference to the section (fig. 152), that the series of stages from the Vosges towards Paris are still in concordant superposition, being very nearly parallel and horizontal, or if they dip it is always towards the middle of the basin, as strata do when deposited at present in tranquil waters. Except some occasional faults, there are no violently inclined or disrupted strata either in the Anglo-Parisian basin or north of the Pyrenean.

When, however, the state of the stratification of these stages on the slopes of the Alps are examined, a very different state of things is encountered. There we find them broken, and thrown into all inclinations, from the vertical to the horizontal; the obvious effects of the catastrophe, which in forcing up the great chain of the Alps burst through the Jurassic formation, disrupting its stages, and throwing them upon the declivities into all inclinations. On examining the sections of the strata as they are ranged upon the slopes of the Alps, we find, notwithstanding the violence to which they have been submitted, the same regular succession of ten stages occurring in the same order as around the Anglo-Parisian basin, where they were deposited successively, and in a state of comparative tranquillity. All this indicates that for long intervals of time previous to the elevation of the chains of the Alps and Pyrenees, the region on which they now stand was covered by the Jurassic seas, upon the bottom of which the strata of the Jurassic formation were deposited, and that it was long after the consolidation of these strata, that the violent action of the fluid matter of the internal parts of the earth, breaking the crust, forced the igneous rocks which now form the Alps and Pyrenees through the disrupted Jurassic stages.

332. Observations made upon the organic deposits of the Jurassic strata fully confirm these views. The shore lines of the Anglo-Parisian and other basins, those outlines marked on the map by the differently tinted shadings, are characterised by those shells which are deposited on the very borders of seas within the play of the tides. The deposits within these are those which take place in the deeper littoral regions, but those which are found upon the section of the strata disrupted upon the slopes of the Alps and Pyrenees, are the classes known to live only in the depths of the ocean. With the exception, therefore, of certain points giving coast indications, the Alps, or rather the space on which they stand, were in the midst of the Jurassic ocean.

333. During this age the island of the Var, already mentioned, was considerably increased. The land of the Vosges and the

Black Forest were also augmented, as well to the west in the direction of Lorraine, as to the east in the direction of Germany, where several islands, left separate in the Triassic age, became united so as to form a single island or continent of considerable magnitude. But while in some places the land was thus increased, in others it was submerged. Thus the continental tract, which in the Palæozoic age extended over France, between St. Malo and Lyons (see map of the Carboniferous period, fig. 148), was in this age submerged by the Breton Strait which connected the Anglo-Parisian and Pyrenean basins. Thus Poitiers and the surrounding region were alternately dry land and submerged by the sea, being submerged in the Silurian, dry in the Carboniferous period, again submerged during the Jurassic age, and finally raised to their present level.

334. It will be also apparent by inspecting the charts of M. Elie de Beaumont and D'Orbigny, that the tract between Toulon and Innspruck, which in the Palæozoic age was dry land, was completely submerged by the Mediterranean basin in the Jurassic age, being subsequently raised to its present elevation.

335. Owing to the extent of the Jurassic deposits in Europe, and the clearness with which they are distinguishable from those which lie below them, the outlines of land and water during that age can be traced with nearly as much precision as the geographical form of the existing continents.

336. The Jurassic geography of central Europe will be further elucidated by the map of M. Elie de Beaumont, fig. 154, here reproduced by permission from the work of M. Beudant.

The great Belgivosgian continent, a part of which only is included in the map of M. D'Orbigny, fig. 153, is here more fully represented. It appears that it extended on the north of the Mediterranean basin from Calais and Dunkirk to Cracow east and west, and from Wesel and Leipsic to Basle and Salzbourg north and south. By reference to fig. 142, 144, it will be seen that in the Silurian and Carboniferous periods Saxony and Bohemia formed a large island, and that another extended from Frankfort to Arras. In the Jurassic age these became united by the upheaving of the land, and formed the Belgivosgian continent shown in figs. 153 and 154. A well-defined coast then extended from Dunkirk to Metz, which, after passing round the two peninsulas, the Vosges and the Black Forest, reached Ratisbon, Vienna, and Cracow, where it was intersected by a strait directed N.W. and S.E.

An island existed between Toulon and Nice, and Corsica was raised above the waters.

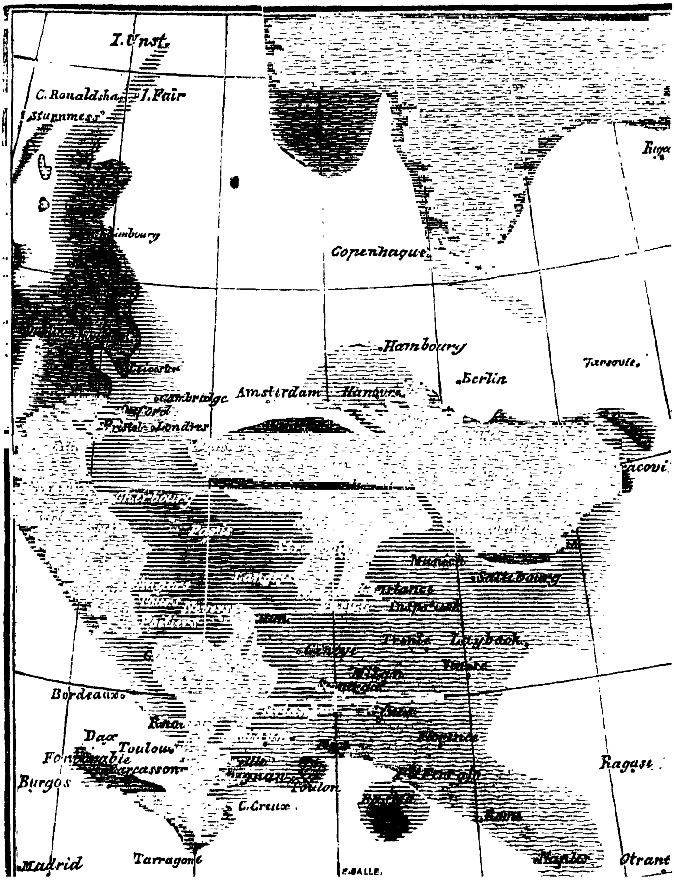

Fig. 154.*—M. Elie de Beaumont's map of Western Europe in the Jurassic Age.

The Scandinavian peninsula remained unchanged since the Carboniferous period.

337. The marine animals of the Jurassic age presented characters strikingly different from those of the preceding epochs. The seas were now inhabited by monstrous animals endowed with vast powers of aquatic locomotion called Ichthyosauri, fig. 7, and

* The dark shading represents land.

Plesiosauri, fig. 155, whose oar-like feet resembled those of the

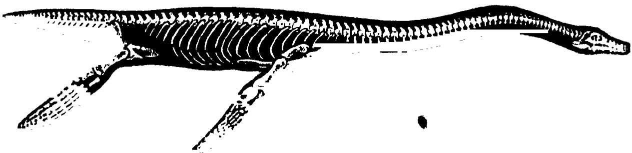

Fig. 155.—The Plesiosaurus.

present sea-tortoise. These animals replaced the sauroid fishes of the Devonian period which long before had disappeared. It was also this age which was signalised by those flying saurians to which palæontologists have given the name Pterodactyles (fig. 156), or wing-fingered. All these monstrous tribes became com-

Fig. 156.—The Pterodactyle

pletely extinct at the close of the Jurassic age. In fig. 161 (p. 1) we have reproduced, after Dr. Buckland, an illustration of the zoology and botany of this age.

338. The producti had altogether, and the spirifers nearly, disappeared, but numerous terebratulæ of other species took their places. The family of ammonites (fig. 8) which had commenced to appear sparingly in the Triassic age now abounded.

This age was also signalised by the appearance for the first

time of the family of *Calmars*, which include the Belemnites and various new bivalve Molluscs.

339. In the seas existed also madreporic reefs or islands similar to those which exist at present in intertropical regions (fig. 202). Lakes were numerous and were inhabited by tribes of fresh water Testacea, whose remains are now found in the Portland beds and elsewhere.

340. Insects of the orders Diptera (flies, gnats), Hymenoptera (bees, ants), and Hemiptera (bugs, water scorpions, plant lice), Crustaceous Isopods (sow bugs), Tectibranche-Molluscs, Cirride-Brachiopods, free Crinoids, severally appeared in this age for the first time upon the earth.

341. The vegetable kingdom presented none of the characteristics of the preceding. The colossal ferns and lycopodiaceæ had disappeared, and had been replaced by new species of the same families. Conifers were abundant in the Lias period, with new species of Cicadeæ. The fruit of a species of palm is found in the same deposit, as well as carbonaceous strata altogether different from those of the carboniferous period. The difference of the quantity as well as the quality of these vegetable deposits indicate in a striking manner the difference of the extent of the continents of the two periods.

This general account of the Jurassic age will render necessary only a very brief notice of its successive periods.

FIRST JURASSIC PERIOD.

342. The geological convulsion which closed the Triassic age having destroyed the animal and vegetable kingdoms, and the tumult having been followed by a period of tranquillity, the seas, subsiding within their limits, deposited the strata which form the first Jurassic stage. These deposits, called by D'Orbigny the Sinemurian stage, from the circumstance of their great development in the neighbourhood of the town of Semur (Sinemurium), correspond with the lower lias of British geologists, the gryphite limestone of Dufresnoy, Elie de Beaumont, and Roemer, and the quadersandstein of other German geologists.

The parts of Europe where this stage appears at the surface round the great Jurassic basins are shown upon the map (fig. 153), by the shading marked 7, being the external boundary of the series of concentric lines surrounding these basins. In England this stage is seen in a continuous zone, extending N.N.E. from Lyme Regis, through the counties of Dorset, Somerset, Gloucester, Worcester, Warwick, Leicester, Nottingham, and Lincoln. It

forms a semicircle in Yorkshire, directing its course to the Tees and Whitby. It will be apparent from the map that the course of this stage in England is only the continuation of its direction in Normandy.

343. This stage is distinguished from the succeeding one by many and evident discordances, and more especially by the isolation of strata, the superior stage being in many places present without the inferior. An example of this is presented at Fontaine-Étoupe-Four, in the department of Calvados in France, where the second, third, and fourth stages rest in concordant stratification on Silurian rocks, without the interposition of this first stage.

344. The seas of this period covered all the southern part of Western Europe from France to Sicily, and deposited their first stage upon the region on which the Alps and Pyrenees now stand. After the lapse of a long interval posterior to their consolidation, as well as that of many other stages subsequently deposited, the Alps and Pyrenees were forced by an internal pressure through the crust, which being broken, these with other strata were disrupted and thrown into various inclinations, some being rendered vertical, while others being compressed horizontally were bent into the form of undulations.

Examples of these effects are numerous. One showing the first Jurassic stage thrown into a vertical position occurs at Gevaudan in the department of the Basses Alpes (fig. 158), and one showing the undulating form produced by horizontal compression occurs at Chaudon à Digne in the same department (fig. 159).

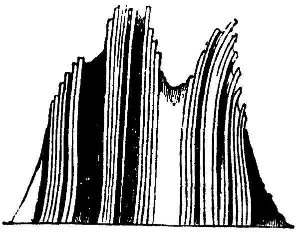

Fig. 158.—Section of first Jurassic stage at Gevaudan.

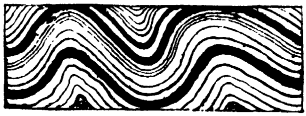

Fig. 159.—Section of first Jurassic stage at Chaudon.

345. After tranquillity was re-established, another fauna and flora was called into existence, a synopsis of which (excepting the annulata) is given in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the First Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	0	1	0	0
	Fishes	1	1	0	0	0
Mollusca.	Cephalopods	4	3	1	0	0
	Gastropods	9	1	8	0	0
	Lamellibranchia	20	4	16	0	0
	Brachiopods	6	2	4	2	0
	Bryozoa	1	0	1	0	0
Radiata.	Echinodermata	3	1	2	0	0
	Polyparia	3	2	1	1	1
	Foraminifera	0	0	0	0	0
	Amorphozoa	0	0	0	0	0
		48	14	34	3	1

The 46 genera of Mollusca and Radiata composing this fauna, so far as they are known, consisted of 174 species.

346. Among the reptiles which lived in these seas were the Ichthyosauri or great fish-lizards, already mentioned (fig. 7), which rivalled in magnitude the largest whales of the present seas. Fishes of new species animated the coasts, and Ammonites (fig. 8), Belemnites and Turrillites abounded. So many new forms signalised the commencement of a new era in animalisation. The order of Dipterous insects appeared for the first time. A new flora adorned the continents in which new species of Cicadeæ and ferns predominated.

347. The convulsion which terminated this period arose probably from a subsidence of the beds of the seas, which, after the re-establishment of equilibrium, caused them to recover their former outline, their shores being only contracted within their former limits.

SECOND JURASSIC PERIOD.

348. The deposits made by the seas of this period, called by D'Orbigny the Liasian stage, correspond with the middle lias or marlstone of British geologists, and the Belemniten-schichte of the Germans. The regions of its appearance are nearly the same as those of the preceding stage.

349. When tranquillity was re-established, a new creation was called into being, a synopsis of the chief part of which is presented in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Second Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	3	1	2	0	0
	Fishes	29	22	7	10	9
Mollusca.	Cephalopods	3	0	3	0	1
	Gastropods	16	2	14	0	0
	Lamellibranchia	25	3	22	1	0
	Brachiopods	3	0	3	0	0
	Bryozoa	0	0	0	0	0
Radiata.	Echinodermata	6	4	2	0	0
	Polyparia	2	1	1	0	0
	Foraminifera	6	6	0	0	0
	Amorphozoa	0	0	0	0	0
		93	39	54	11	10

The genera of Mollusca and Radiata alone consisted of at least 300 species.

350. The seas swarmed with enormous Saurians in greater numbers than ever, including new varieties of the Ichthyosauri and Plesiosauri. The former had a fishlike form, and the latter a neck of enormous length, by means of which it could dart its mouth at a distant prey, its body still being immersed in the water (fig. 155). With these were associated the singular flying reptiles, called Pterodactyles (fig. 156). A vast variety of new species of fishes disputed the seas with swarms of Ammonites (fig. 8), Nautili, and Belemnites; while the coasts abounded in endless varieties of shells, such as Pterocera, Ditremaria, Inoceramus, with Asteria, Ophiuri, Echinodermata (fig. 160), and Foraminifera.

351. Although all traces of terrestrial fauna have disappeared, in the remains of this period there can be little doubt that insects and other Annulata existed. Of Crustacea only one genus, *Coleia*, has been found.

352. The land was richly clothed with vegetation, consisting chiefly of ferns, cicadeæ, and conifers of elegant foliage, of which 65 species are known.

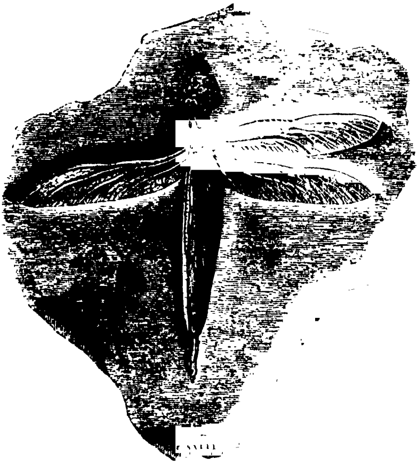

Fig. 166.—Fossile Dragon-fly (Libellula).

THE PRE-ADAMITE EARTH.

CHAPTER VI.

Third Jurassic Period. 353. Mineral character of this stage.—354. Synopsis of the animal kingdom.—355. Outlines of land and water.—356. Land animals and vegetation. Fourth Jurassic Period. 357. Mineral character of the stage.—358. Synopsis of the animal kingdom.—359. Land fauna. Fifth Jurassic Period. 360. Mineral character of the stage.—361. Synopsis of the animal kingdom.—362. Examples of the fauna.—363. Traces of land fauna—Phascolotherium and Thylacotherium.—364. Examples of the flora.—365. Convulsion which closed the period. Sixth Jurassic Period. 366. Mineral character of the stage.—367. Synopsis of the animal kingdom—disappearance of the Ichthyosauri.—368. Remarkable changes in the outlines of land and water.—369. Extent of the Mediterranean basin — submersion of the great Russian continent. Seventh Jurassic Period. 370. Mineral character of this stage.—371. Synopsis of the animal kingdom.—372. Creation of several orders of insects.—373. Specific forms of Mollusca and Annulata.—374. Outlines of land and water.—375. Marine flora.—376. Land animals.—377. Surprising perfection of the fossil forms—observations of Buckland and Lyell.—378. Further proofs of the suddenness of the catastrophe which terminated this period.—379. Indication of the general prevalence of tropical climate. Eighth Jurassic Period. 380. Mineral character of the stage.—381. Synopsis of the animal kingdom.—382. Elevation of Russia above the waters.—383. Character of the fauna.

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THIRD JURASSIC PERIOD.

353. THE traces from which a convulsion closing the preceding period has been inferred, differ in nothing from those mentioned in the former period.

The strata deposited by the seas of this period, called by D'Orbigny the Toarcian stage, from the town of Thouars (Toarcium), in France, correspond with the upper Lias of British geologists, the Brauner Jura, and Opalinusthon of the Germans. Its extent can be traced on the map (fig. 153), by the shading marked 9.

354. The new creation, exclusive of the Annulata, is shown in the following table:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Third Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	6	3	3	3	3
	Fishes	11	2	9	1	1
MOLLUSCA.	Cephalopods	7	4	3	3	3
	Gastropods	17	0	17	1	0
	Lamellibranchia	29	2	27	0	0
	Brachiopods	4	0	4	1	0
	Bryozoa	0	0	0	0	0
RADIATA.	Echinodermata	2	0	2	0	0
	Polyparia	3	2	1	2	2
	Foraminifera	3	2	1	0	0
	Amorphozoa	2	0	2	0	0
		84	15	69	10	9

The Mollusca and Radiata consisted of 288 species.

355. The outlines of land and water did not suffer any considerable change. Besides the genera of marine reptiles already mentioned, the strange forms of the Mistriosauri and Macrospondili

now roamed along the coasts, besides various new forms of Mollusca and Radiata.

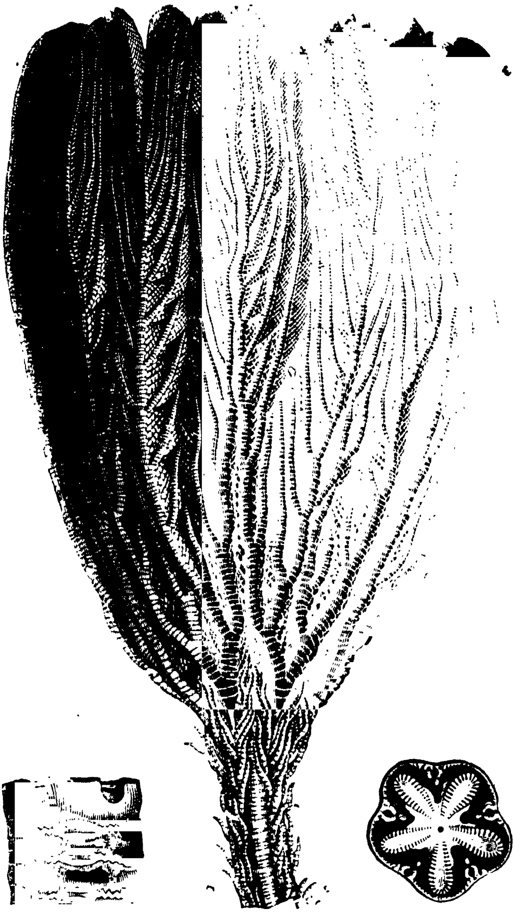


Fig. 160.—Pentacrinus fasciculosus (Echinoderm.)

356. Scarcely a trace of land animals remains, and those of plants but few and rare. Some conifers and cryptogamous plants however are found.

FOURTH JURASSIC PERIOD.

357. The strata deposited in this period, called by D'Orbigny the Bajocian stage, from the French town of Bayeux (Bajoce), correspond with the inferior Oolite of British geologists. Its course on the surface is indicated on the map (fig. 153) by the shading number 10.

358. The animal kingdom of this period is shown in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fourth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	0	0	0	0	0
	Fishes	5	2	3	1	1
Mollusca.	Cephalopods . .	6	3	3	0	0
	Gastropods . .	21	4	17	1	0
	Lamellibranchia	40	6	34	1	0
	Brachiopods . .	5	1	4	0	0
	Bryozoa . . .	8	8	0	1	1
Radiata.	Echinodermata .	14	10	4	1	0
	Polyparia . . .	18	7	11	1	1
	Foraminifera .	2	1	1	0	0
	Amorphozoa .	10	3	7	0	0
		129	45	84	6	3

359. Of the terrestrial fauna of this period nothing is known, and a few plants only, consisting of Cicadeæ and doubtful Monocotyledons remain.

FIFTH JURASSIC PERIOD.

360. This stage, the Bathonian of D'Orbigny and D'Halloy, corresponds with the great Bath oolite, Forest marble, and Stonesfield slate of British geologists.

361. When tranquillity was re-established after the catastrophe which terminated the fourth period, a new creation appeared on the earth, of which the chief part is shown in the following table :—

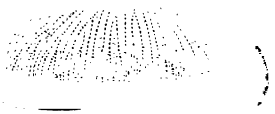
FIFTH JURASSIC PERIOD.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Fifth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	2	2	0	2	2
	Birds	0	0	0	0	0
	Reptiles	5	4	1	1	1
	Fishes	21	5	16	5	3
Mollusca.	Cephalopods	5	0	5	0	0
	Gastropods	25	6	19	0	0
	Lamellibranchia	38	4	34	0	0
	Brachiopods	6	0	6	0	0
	Bryozoa	19	9	10	2	1
Radiata.	Echinodermata	20	6	14	1	0
	Polyparia	19	8	11	4	3
	Foraminifera	5	0	5	1	0
	Amorphozoa	10	1	9	1	1
		175	45	130	17	11

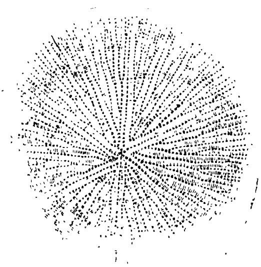
362. An example of the polyparia of this period is shown in figs. 160, 161*, 162.

Fig. 161*.



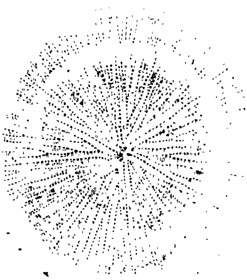
Side view.

Fig. 162.



Upper surface.

Fig. 163.



Lower surface.

Anabacia orbulites (Polyparia).

Together with new species of Pterodactyles, fig. 156, there lived in the seas of this period not less strange reptile forms, to which the names Pœcilopleuron, Teleosaurus, and Megalosaurus have been given.

363. A terrestrial fauna at length left traces of its existence. Mammifers now presented their first traces. Two land monsters, referred to this class, found in this stage, have been called Phascolotherium and Thylacotherium. Specimens of the lower jaw of the former were found in the oolitic limestone of Stonesfield. It is a small animal allied to the Marsupial family, and takes its name from the Phascolomys of New South Wales.

364. A great variety of species of ferns, Cicadeæ, and conifers have been found among the remains of this period, with a few Marsileaceæ, Lycopodiaceæ, and Equitaceæ.

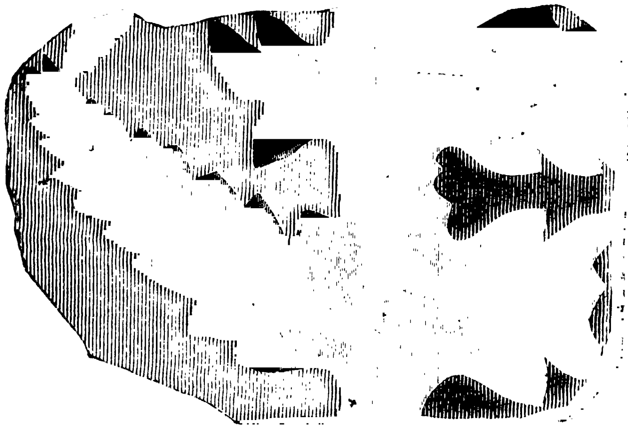


Fig. 161.—Phlebopteris Phillipsii.

365. One of the causes which are assigned to the catastrophe which closed this fifth Jurassic period, is the sudden sinking of the continent, which was elevated at the close of the palæozoic age, and which extended over Central and Northern Russia. This vast tract was submerged during the sixth Jurassic period, and the ocean at the same time flowed over the entire province of Cutch in India. The sea also covered the department of the Sarthe in France. Effects of this disturbance are traced in France, even where no disturbance of strata exists by the state of the superposed littoral deposits. Its effects are also seen in the polishing of the superior strata at Lyons, showing the result of a long-continued action of the waters. In fine, these indications are confirmed by the complete destruction of the fauna and flora of the period.

SIXTH JURASSIC PERIOD.

366. This stage, called the Callovian, corresponds to the Oxford clay and Kelloway Rocks of the British geologists, from the latter of which it takes its designation.

367. The animal generic forms which lived in this period, exclusive of the Annulata, are enumerated in the following table :—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Sixth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	2	1	1	1	0
	Fishes	2	?	2	?	
Mollusca.	Cephalopods . .	6	2	4	1	1
	Gastropods . .	15	0	15	0	0
	Lamellibranchia	31	0	31	0	0
	Brachiopods . .	3	0	3	0	0
	Bryozoa . . .	2	0	2	0	0
Radiata.	Echinodermata .	11	0	11	0	0
	Polyparia . . .	1	0	1	0	0
	Foraminifera .	0	0	0	0	0
	Amorphozoa .	0	0	0	0	0
		73	3	70	2	1

It appears, therefore, that of the 73 genera which existed, only three were new, two of which were generic forms of Cephalopods, called Rhychoteuthis and Palæoteuthis. This period was

Fig. 165.—Ammonite—Jason.

remarkable for the prevalence of Ammonites, denominated Limula, Athleta, Jason (fig. 165), as well as the Trigonia elongata, Plicatula peregrina, Astrea dilatata, and Terebratula Diphya.

The Ichthyosaurus appeared for the last time in this period.

368. The outlines of sea and land during this period underwent some remarkable changes. The convulsions which ter-

minated the fifth period raised the bottoms of the Breton and Vosgian Straits, so as to separate completely the Anglo-Parisian from the Pyrenean and Mediterranean basins, and thus to connect Brittany on the one side, and the Vosgian continent on the other, by two isthmuses.

369. The Mediterranean basin extended across the Tyrol, and into Switzerland, as far as Soleure, and probably even to the Crimea. But the greatest change produced by this convulsion was the subsidence of the great Russian continent, which had continued above the sea since the close of the palæozoic age, and the consequent extension of the seas of this sixth period over all Russia, from the 48th degree of latitude to the Frozen Ocean. It appears also from the organic remains of Mollusca and Radiata, that these seas extended on the south, without interruption, to the 9th degree of latitude, thus covering the entire extent of Asia, from the province of Cutch to the polar circle.

SEVENTH JURASSIC PERIOD.

370. The deposits of this period, called by D'Orbigny the Oxfordian stage, correspond with the upper strata of the Oxford clay, or the dark-blue clay of Oxfordshire and the Midland counties, the thickness of which in England, according to Lyell, is sometimes 500 feet. In the south-west of France, and in the Alps, it measures from 320 to 500 feet.

371. In the following table we give a synopsis of the generic forms of this period, excepting the Annulata:—

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Seventh Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Charac-teristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	11	10	1	9	9
	Fishes	28	14	14	18	13
Mollusca.	Cephalopods	9	5	4	2	2
	Gastropods	21	0	21	0	0
	Lamellibranchia	41	2	39	1	1
	Brachiopods	8	0	8	0	0
	Bryozoa	4	0	4	0	0
Radiata.	Echinodermata	22	9	13	8	7
	Polyparia	22	6	16	4	3
	Foraminifera	0	0	0	0	0
	Amorphozoa	16	5	11	3	2
		182	51	131	45	37

Of Crustacea 31 were created, all of which became extinct at the close of the period, so that the total number of generic forms ascertained to have lived is 213, of which 82 were created, and 131 revived, exclusive of other Annulata, the existence of which has been determined but their numbers unascertained.

372. This period is signalised by the first appearance of insects, of the orders Hemiptera (bugs, water-scorpions, plant-lice), Hymenoptera (bees, ants), and Lepidoptera (butterflies, moths), and of Isopodous Crustacea, and the prevalence of testaceous spongearia, pterodactyles, pycnodide fishes, and decapod crustacea.

373. Of Mollusca and Annulata of this period, 729 species have been catalogued, and the total number of species of all classes could not have amounted to less than 800.

In fig. 166 is shown a specimen of the insects of this period, and in fig. 167, one of the Annelids.

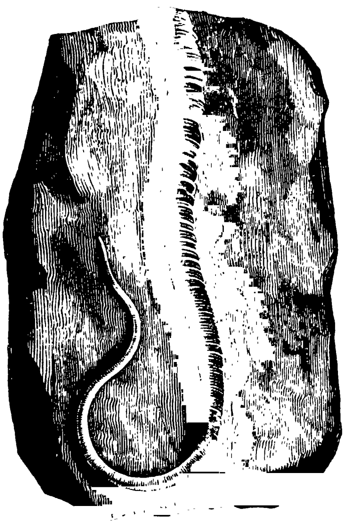


Fig. 167.—Serpula flagellum.

374. The seas retained their former limits; those of the Parisian and Pyrenean basins, however, retiring as before stated, so as to leave a new band of surrounding coast uncovered. They extended over the same parts of Europe, and were continuous on the one side to Asia Minor, and on the other into Russia, as is proved by the prevalence of the same marine species in the strata. The Breton and Vosgian Straits were still replaced by isthmuses.

375. Adolphe Brongniart has enumerated a considerable assemblage of marine plants of this period, consisting chiefly of Cryptogamous Algæ.

376. The continents were not less animated than the seas. Besides several orders of insects, and the generic reptile forms of the preceding periods, 10 new reptile genera were called into existence, including the Gnathosaurus, Pleurosaurus, Geosaurus, and Spondylosaurus, which, as well as new species of pterodactyles, abounded. M. Brongniart has also given a list of the

terrestrial flora of this period, which consisted in a great degree of doubtful monocotyledons.

377. The sudden character of the catastrophes, by which from period to period the successive faunas and floras were destroyed, is strikingly illustrated by the perfect state in which the remains of many of the saurians have been found. Of those which were deposited in these strata, many must, as Sir C. Lyell observes, have met with sudden death and immediate burial, and the same indications are observable in the case of all the other stages. "Sometimes," says Dr. Buckland, "scarcely a single bone has been removed from the place it occupied during life, which could not have happened had the uncovered bodies of these saurians been left, even for a few hours, exposed to putrefaction, and to the attacks of fishes and other small animals at the bottom of the sea." * Not only are the skeletons of the Ichthyosauri entire, but sometimes the contents of their stomachs still remain between their ribs, so that we can discover the species of fish on which they lived, and the form of their excrements. Not unfrequently there are layers of these coprolites (fossilised excrements) at different depths in the lias at a distance from any entire skeletons of those marine lizards, from which they were derived, as if the muddy bottom of the sea received small sudden accessions of matter from time to time, covering up the coprolites and other exuviæ, which had accumulated during the intervals. It is further stated, that at Lyme Regis, those surfaces only of the coprolites, which lay uppermost at the bottom of the sea, have suffered partial decay from the action of the water, before they were covered and protected by the muddy sediment that had afterwards permanently enveloped them.†

378. The remains of cephalopods give like indications of sudden death. Numerous specimens of the Calamary, or pen-and-ink fish (Geotenthis Bollensis), have also been met with in these strata at Lyme, with the ink-bags still distended, containing the ink in a dried state, chiefly composed of carbon and but slightly impregnated with carbonate of lime. These, like the Saurians, must therefore have been promptly buried, for if long exposed after death, the membrane containing the ink would have been decayed.‡

379. The identity of the specific forms of the fauna of this period, in all latitudes, from 40° to the Frozen Ocean, shows that

* Bridg. Treat. p. 125.

† Lyell's Manual, p. 327 ; De la Beche, Geol. Res., p. 334 ; Buckland, Bridg. Treat., p. 307.

‡ Buckland, Bridg. Treat., p. 307.

no difference of climates such as the present then existed. All had the intertropical character.

EIGHTH JURASSIC PERIOD.

380. The strata deposited during this period, called by D'Orbigny the Coralline stage, correspond to coral rag of British and German geologists.

381. Exclusive of annulata, the following table represents the fauna of this period.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Eighth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	1	0	1	0	0
Mollusca.	Cephalopods	3	0	3	0	0
	Gastropods	28	2	26	2	0
	Lamellibranchia	41	2	39	2	1
	Brachiopods	4	0	4	0	0
	Bryozoa	3	0	3	0	0
Radiata.	Echinodermata	24	5	19	11	3
	Polyparia	48	26	22	25	19
	Foraminifera	3	1	2	1	1
	Amorphozoa	6	0	6	0	0
		161	36	125	36	24

382. In Russia, all that tract which extended to the Frozen Ocean, and which had been submerged during the seventh period, was now again raised above the waters, and became land. In England, France, and Germany the general forms of the land remained the same, but their extent was augmented by the general retirement of the shores of the seas.

383. The fauna of this period was remarkable for numerous polyparia of the coral class, by which reefs were formed similar to those which exist in the present seas. It was at this epoch that the Diceras, Nerinea, Purpurina, Hemicidaris (figs. 168, 169), Acrocidaris, Millecrinus, and Apiocrinus attained their greatest specific development.

384. In the total absence of all organic remains of a terrestrial fauna, we must infer by analogy that the fauna of this must have been related to that of the antecedent periods. The flora, according to the observations of M. Brongniart, consisted of ferns, cicadeæ, and conifers of peculiar species.

385. Although it is probable that the close of this stage was the result of a convulsion which originated at some point distant

Fig. 168.

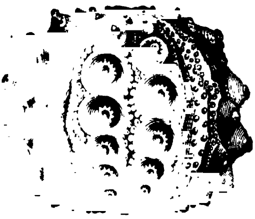


Fig. 169.

Hemicidaris crenularis.

from the range of geological observation, there are indications of some disturbance by the absence of the superior strata in the Alps, from Grasse to Gap, which may probably be connected with the catastrophe which closed this eighth period.

NINTH JURASSIC PERIOD.

386. The deposits of this period correspond with the Kimmeridge clay of the British geologists.

387. A general view of the fauna, with the usual exceptions, is presented in the following table.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Ninth Jurassic Period.

		GENERA.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
VERTEBRATA.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	7	4	3	4	1
	Fishes	7	?	7 ?	3	?
MOLLUSCA.	Cephalopods	3	0	3	0	0
	Gastropods	15	0	15	0	0
	Lamellibranchia	31	0	31	3	0
	Brachiopods	3	0	3	0	0
	Bryozoa	1	0	1	0	0
RADIATA.	Echinodermata	10	0	10	1	0
	Polyparia	1	0	1	0	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	0	1	0	0
		79	4	75	11	1

388. The close of the last period was marked by the final extinction of at least 36 generic forms. The four generic forms of reptiles which appear for the first time in this ninth period are the Stenosaurus, Streptospondylus, Emys, and Platemys, of which the Stenosaurus is peculiar to the period and characteristic of it, not re-appearing in the next or any subsequent period. Of the reptile genera of former periods, those which re-appear in the present, and finally became extinct at its close, are the Plesiosaurus, Teleosaurus, and Pliosaurus.

Independently of the species of the other classes which lived in this period, 186 species of mollusca and radiata have been catalogued and described by M. D'Orbigny.

389. The seas were circumscribed by nearly the same limits, retiring nevertheless a little within their former shores. They were inhabited by nearly the same assemblage of genera, the species being, however, altogether different. The cephalopods were not numerous, the prevailing marine genera consisting of gastropods, and lamellibranchia.

390. The land, independently of some revived genera, was inhabited by the saurian reptiles Stenosaurus and Streptosaurus, and by the tortoise forms, denominated Emys and Platemys, all of which were probably amphibious.

No vegetable remains of this period have been found.

TENTH JURASSIC PERIOD.

391. The deposits of this period correspond with the Portland beds. They lie generally upon the Kimmeridge strata of the preceding period.

392. A general view of the fauna, with the previous exceptions, is given in the table on the next page.

Of the mollusca and radiata 63 species have been described.

393. The seas of this period, like those of the former, preserved the general configuration of their outlines, still retiring a little within their former shores. The marine fauna among fishes was increased by the Meristodon, and among mollusca by the Cyclas. The principal saurians of the last period disappeared from the coasts, and were replaced by the Cetiosaurus. This marine reptile must have rivalled the existing whale in magnitude, some specimens indicating a total length of 40 to 50 feet. The bones found in some strata in England, of somewhat more recent date, may have been carried up from the sea along the bed of a river by the tide, or the animal when living, as is often at present the case with existing cetaceans, may have wandered up the river, and dying, have been deposited in its bed.

Synopsis of the Animal Kingdom (exclusive of the Annulata) during the Tenth Jurassic Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	2	1	1	0	0
	Fishes	6	1	5	2	1
Mollusca.	Cephalopods .	3	0	3	0	0
	Gastropods . .	6	0	6	1	0
	Lamellibranchia	16	1	15	0	0
	Brachiopods . .	0	0	0	0	0
	Bryozoa . . .	0	0	0	0	0
Radiata.	Echinodermata .	2	0	2	0	0
	Polyparia . . .	1	0	1	0	0
	Foraminifera .	0	0	0	0	0
	Amorphozoa .	0	0	0	0	0
		36	3	33	3	1

394. The close of this period, which marks the termination of the Jurassic age, is distinctly indicated by numerous dislocations and isolations of the strata, denoting upheavings and depressions in many regions. These phenomena demonstrate the complete separation of the last stages of the Jurassic from the first of the succeeding age. M. Elie de Beaumont considers the catastrophe which raised the mountain systems of the Côte d'Or (215), of Monte Pila, and the Erzgebirge, the prevailing direction of which is W. 40° S. and E. 40° N., as that which terminated the Jurassic age.

The Cretaceous Age.

395. The group of strata to which geologists have given the name of the Cretaceous or chalk formation, being deposited upon the Jurassic group, must have been the result of the succeeding geological age. Its stratigraphical limits, as we shall here consider it, are the Purbeck beds below, and the Maestricht beds above. Some British geologists, including Sir C. Lyell, place the former as the uppermost strata of the Oolitic formation; while others, including Sir H. de la Beche, give it to the Cretaceous group. By reference to the tabular section (47), it will be seen that the title given to this Cretaceous group must not be understood as implying that chalk is the exclusive character of the strata.

The superior strata of this formation are not present in England, and hence they take their name from Maestricht, where they are most developed.

396. The complete series of strata of the Cretaceous formation, are found succeeding each other in their proper order in the continuation of the section given in fig. 152. This continuation, extending from Sommevoire and Vassy to Vertus, is given in fig. 170. The Cretaceous group terminates a little to the west of Vertus, and the Tertiary or succeeding formation appears from that point to Paris. We shall refer to this latter part of the section when we come to notice the Tertiary age.

CRETACEOUS FORMATION.

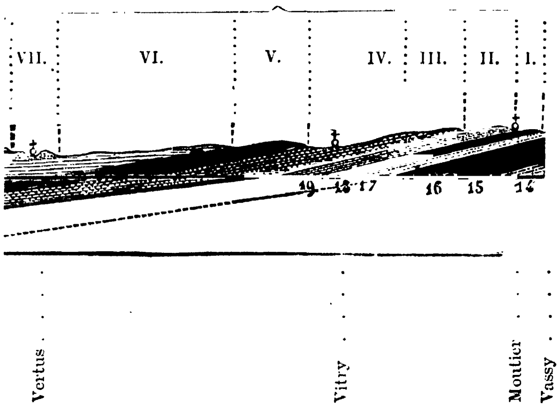


Fig. 170.—Section from Vassy to Vertus, being part of the great section from the Vosges to Paris.

397. Proceeding upon observations and reasoning similar to those explained in reference to the Jurassic formation (322), M. D'Orbigny resolves the Cretaceous formation into seven stages, to which names are given, derived from the localities severally where the strata are most exposed at the surface, and where therefore they have been most observed. To avoid encumbering the memory of the reader with a nomenclature so complex, we shall here, as in the former cases, designate the stages by their numerical order, proceeding from the lowest upwards, and the periods of their deposition into which the Cretaceous age is resolved, also by their numerical order, proceeding from the earliest to the latest.

398. It will be convenient, however, as in the former case, to indicate the names given to the stages and their approximate mean thickness severally.

No. of stage.	Name.	Origin.	Thickness. Feet.
VII.	Danian . .	Denmark	50
VI.	Senonian . .	Sen (Senones) . . .	1000
V.	Turonian .	Touraine . . .	700
IV.	Cenomanian .	Mans (Cenomanum) .	1600
III.	Albian . .	Aube (Alba) . . .	150
II.	Aptian . .	Apt (Apta Julia) . .	700
I.	Neocomian .	Neufchatel (Neocomum)	8000
		Total . . .	12200

So that the total thickness of the formation is above 12000 feet, or 2¼ miles, the chief part being occupied by the first or lowest stage. The mineral composition of these stages will be stated when we come to notice them separately.

399. While at some points these seven stages are found in regular superposition, in others particular stages are absent. Thus, while on the northern and eastern border of the Anglo-Parisian basin the series is complete, in other localities great discordances of stratification are observed, as well by the varying dips of the contiguous strata as by the absence of one or several stages of the series. These are the grounds upon which the entire Cretaceous formation is stratigraphically set apart from the Jurassic, and upon which the seven stages into which it is resolved are inferred to be independent, and those conclusions are confirmed by observations made upon the arrangement of the deposition of the organic remains, which appear to be distributed in seven distinct layers, corresponding with the stratigraphical limits of the stages.

Fig. 202.—CORAL REEF.

THE PRE-ADAMITE EARTH.

CHAPTER VII.

400. Zoological character of the Cretaceous age.—401. Distribution of the species among the stages.—402. General conclusions.—403. Changes of the outlines of land and water.—404. Elie de Beaumont's map of Western and Central Europe—great geographical changes.—405. The Pyrenean basin.—406. Outlines of sea and land in Central Europe. —407. Site of the Alps.—408. Cretaceous geography of France and England—D'Orbigny's map. — 409. Anglo-Parisian basin.— 410. The changes incidental to it from period to period.—411. Outlines of the basin in England.—412. Pyrenean basin—Mediterranean basin.—413. Animal kingdom—uniform tropical climate at all latitudes.—414. Prevalence of undulations of the surface—seven violent perturbations. First Cretaceous Period. 415. Dimensions and mineral composition of the stage—synopsis of animal kingdom. 416. Reptiles of this period—Iguanodon and Hylæosaurus.—417. Flora of this period. Second Cretaceous Period. 418. Mineral character of the stage.—419. Synopsis of animal kingdom.—420. Outlines of land and water.—421. Marine fauna.—422. Vegetable kingdom.—423. Uniform tropical climate.—424. Close of the period. —Third Cretaceous Period : 425. Mineral character of the stage. —426. Synopsis of the animal kingdom.—427. Outlines of land and water.—428. Marine and terrestrial fauna.—429. Close of the period.—Fourth Cretaceous Period. 430. Mineral character of the stage.—431. Synopsis of the animal kingdom.—432. Outlines of land and water.—433. Marine fauna.—434. Marine flora.—435. Undulations of the ground.—436. Close of the period. Fifth Cretaceous Period. 437. Mineral character of the stage.—438.

Synopsis of the animal kingdom.—439. Outlines of land and water. —440. Rich vegetation.—441. Great extent of land in Russia, South America, and India—termination of the period. SIXTH CRETACEOUS PERIOD. 442. Mineral character of the stage.—443. Synopsis of the animal kingdom.

400. THE Cretaceous age is zoologically distinguished from the Jurassic by the absence of upwards of 180 generic forms which existed in the previous age, and from the succeeding age by the absence of upwards of 500 genera not created until the succeeding one—these 500 genera consisting of 24 orders of animals, as follows:

	Orders.
Mammifers	11
Birds	5
Reptiles	2
Fishes	1
Crustacea	2
Insects	1
Mollusca and Radiata	2
Total	——

401. During this age about 270 genera were created, but it is by the specific forms that its fauna can be more distinctly characterised. These consisted of about 5000 species, of which about 700 belonged to the vertebrata and annulata. The manner in which the species of mollusca and radiata are distributed among the stages is as follows:—

Stages.	No. in two or more species.	No. limited to each stage.	Totals.
I.	7	844	851
II.	8	148	156
III.	8	402	410
IV.	8	841	849
V.	3	377	380
VI.	5	1574	1579
VII.	3	63	66
	42	4249	4291

The same species being repeated in the second column, a corresponding deduction from the total number of common species must be made, which will reduce the actual number of such common species to 21, being only a half per cent. of the total number.

402. From a general analysis of the facts, the following conclusions may be inferred:—

1° That there existed in the Cretaceous age above 5000 species of animals altogether distinct from those of the preceding and

following ages, and which therefore are characteristic of the Cretaceous age.

2° That this total number consisted of seven distinct groups, which existed successively during the seven periods of the Cretaceous age, their remains being deposited in the seven superposed stages which compose the Cretaceous formation.

3° That each period therefore had its own special fauna, having nothing in common with those of the preceding or succeeding periods.

4° That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed a half per cent. of the total number of species discovered.

403. When tranquillity had been re-established after the catastrophe which closed the Jurassic age, the changes which had taken place in the levels of the solid surface of the earth caused the waters to settle into new beds, and gave a modified outline to land and sea. The contours of the seas of this period are now shown by the forms and limits of the Cretaceous strata, subsequently raised above the waters.

404. The outlines of land and water in Western and Central Europe, in the Cretaceous age, as sketched by M. Elie de Beaumont, are shown in the map (fig. 171).

The three great islands of the Jurassic age which appear in the map (fig. 154), were now connected, and their coast-lines completely changed. The northern part of Belgium was submerged, and Brussels, which in the former age was inland, was now on the coast. Arras, Calais, and Dunkirk, which were on or near the coast, were now at the bottom of a large gulf, in the midst of which was Paris, and at the southern part Tours. The town of Poitiers, which was situate in a strait, was now on the coast of the southern extremity of this gulf, which the reader will readily identify with the Anglo-Parisian basin so often referred to. London and Cambridge were at the bottom of this sea, the shores of which, bending westward, formed a bay, which might be called the gulf of Exeter, that city being at its westward limit. Oxford was on the coast of England, which, after jutting out eastward to a point near the site of Cambridge, turned northwards to Edinburgh. Holland and a large part of Prussia and Poland, including the cities of Amsterdam, Hamburg, Berlin, and Warsaw, were altogether submerged.

An isthmus connected the central tract of France with Brittany, at that time part of a continent, which, extending across the channel, was continued to the extreme north of Scotland, being there probably united with the Hebrides.

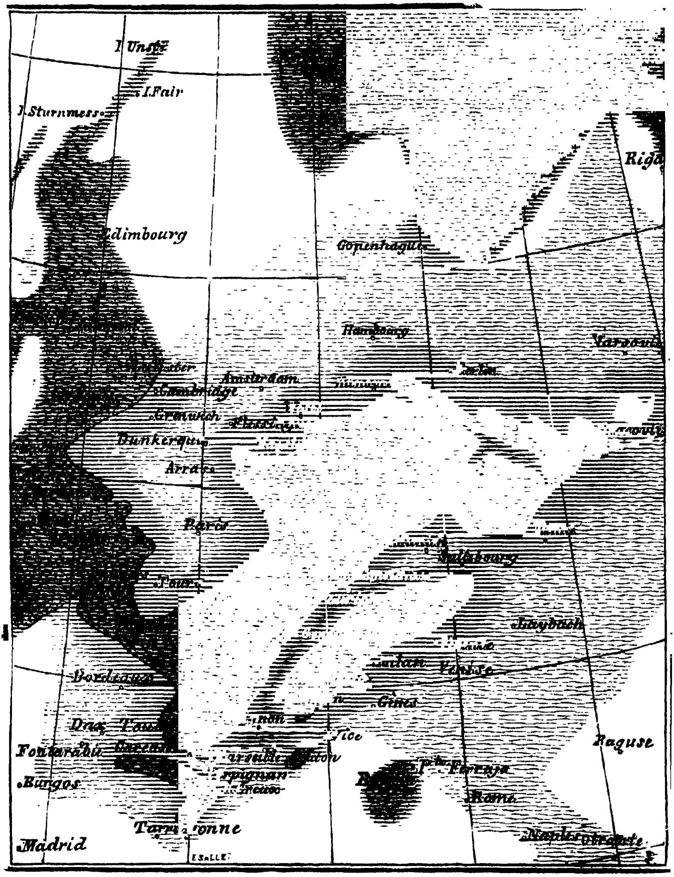


Fig. 171.*—Map of western and central Europe in the Cretaceous Age, sketched by M. Elie de Beaumont.

405. The Pyrenean basin, as will presently appear, did not exist at the commencement of the Cretaceous age, but subsequently to its third period reappeared, its waters covering the greater part of Spain, including Madrid, Burgos, and other towns, as shown on the map. Marseilles and Perpignan were at the bottom of a strait which bounded the southern part of the great central tract. A large

* The dark shading represents land.

island extended in the direction N.N.E. and S.S.W. from Briançon to Innspruck, separated from the main tract by a strait which covered that part of Europe now occupied by Switzerland and the chain of the Swiss Alps. A local sinking of the land between Dresden, Prague, and Brünn, in the middle of Germany, produced an extensive lake in that country, which in the Jurassic age was an uninterrupted tract of land. See map, fig. 154.

406. The Vosges Mountains, previously washed by the ocean, were now completely enclosed by the continental tract which connected Bohemia with the central plateau of France. The sea, which covered so large a part of these countries, now retired, leaving Langres, Nevers, Autun, and Lyons within the land. The south-eastern coast of the great central continent extended from Cracow a little to the north of Vienna and Munich, both of which were covered by the Mediterranean basin, following Strasburg, Bâle, and Lyons, to Carcassonne, where the Pyrenean and Mediterranean basins were connected by a strait between Perpignan and Bayonne. Bordeaux on the west and Avignon on the east were at the bottom of the sea.

407. The future base of the chain of the great Alps was then marked by the island already mentioned, which appears on the map between Salsburg and Briançon, on which Turin, Trente, and Innspruck are now placed. Toulon was on an island to the south of this, and Corsica already formed an island further south. The chief part of Italy was at the bottom of the Mediterranean basin. The Scandinavian peninsula had remained nearly as in the Jurassic age.

408. The geography of France and England during the Cretaceous age is shown upon a large scale and with more detail in the map (fig. 172), drawn by M. D'Orbigny and reproduced here by permission. In this map the seas are marked with the dark shading, and those parts which in previous ages were submerged are shown by three tints, indicated at the top of the map. The deposits of six of the successive periods of the Cretaceous age are marked as follows:—

I 17	III 19	V 21
II 18	IV 20	VI 22

409. It will be seen that the borders of the Anglo-Parisian basin on the south-east were, as in the former age, gradually contracted from period to period, that of the first period (17) being outermost, the next (18) within it, and so on, one being within the other until the last period. This regular succession of deposits is observable to a certain point of the border near Nevers, on the map, beyond which on south and west the exterior band of deposit is not, as

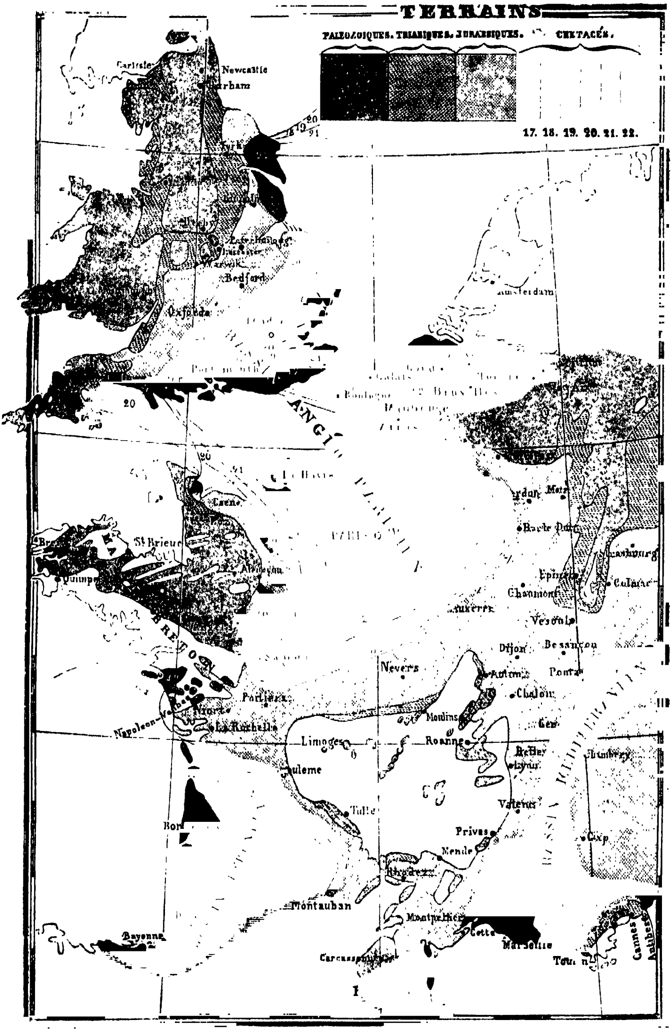


Fig. 172.—Map of France and England in the Cretaceous Age, drawn by M. D'Orbigny.

before, that of the first, but that of the fourth Cretaceous period (20).

410. The interpretation of this fact is evidently a change of relative level of the land along this border during the first four periods of the Cretaceous age. In the first, second, and third periods the border was subject to a gradually increasing depression, which after each period caused the shore of the sea to advance outwards, the shore of the second period (18) being outside that of the first (17), that of the third (19) outside that of the second (18), and in fine that of the fourth (20) being outside that of the third (19). The consequence of this is, that the fourth stage of the Cretaceous formation along this part of the coast lies over and conceals the previous deposits forming the first (17), second (18), and third (19) stages. But after the fourth period the relative levels must have undergone a contrary change, causing the borders of the sea to have retired inwards, or eastwards, from period to period, so that between the fourth and fifth period a band of deposit of the fourth stage (20) remained uncovered, and after the next period another (21), and so on to the end of the Cretaceous age.

411. The irregularity indicated above, as having taken place on the western side of the Paris basin, might have been expected to have continued across the channel, and to reappear along the English border of the same basin. Such, however, is not found to be the case; for, as indicated in the map, the successive stages of the Cretaceous period from the first (17) to the last appear along the northern border of the basin from Dorsetshire to Yorkshire, succeeding each other in the same regular order as in the southern border in France. It would, therefore, appear that the undulation which produced the irregularity observable along the western border adjoining Brittany must have been littoral; that is, in a direction at right angles to the N.W. and S.E. borders of the basin.

412. An examination of the Pyrenean basin discloses a singular state of things in accordance with that observed in the western border of the Parisian basin. The first three stages of the Cretaceous formation are altogether absent from the Pyrenean basin, which only received the deposits of the four last periods. M. D'Orbigny has inferred from this that during the first three periods of the Cretaceous age, the ground upon which the Pyrenean basin is placed was raised above the level of the sea, but that the convulsion which closed the third Cretaceous period caused it again to sink so as to be covered by the sea, and that it thus remained submerged during the last four Cretaceous periods. The border retiring from period to period is indicated on the map,

so as to leave band after band of the successive deposits each uncovered by the other along its NE. border.

In the Mediterranean basin all the stages are presented, though in an irregular and dislocated state.

413. The animal kingdom during the Cretaceous age was destroyed and reappeared in each of the seven periods. To the terrestrial animals, such as birds, reptiles, and insects, and the marine animals included in the class of fishes, mollusca, echinodermata, polyparia, foraminifera, and amorphozoa, which previously existed, must be joined for this age cycloid and ctenoid fishes (salmon and perch), and various forms of foraminifera hitherto unknown. This age was also signalised by the prevalence of cirridated brachiopods, bryozoa and testaceous spongiaria. Ammonite shells also, of the most elegant and various forms, abounded, which disappeared for ever after this epoch.

The presence during the entire Cretaceous age of the same genera and species of animals, from the line to the 56° of latitude on both sides of the world, prove that these regions, so entirely different in their climate at present, had a uniform temperature, proceeding evidently from the neutralising effect of the central heat of the earth, and which temperature was tropical.

414. Throughout the whole of this age, all that part of the earth to which geological research has been directed, was subject to the same slow and gradual undulations, as have been observed during the human period on the Scandinavian peninsula and elsewhere.

On seven different occasions, however, more violent geological perturbations took place, which swept from the earth and seas every living thing; and after these great catastrophes, when nature was tranquillised, Almighty power once more repeopled the land and the water, clothing the former with new vegetation.

FIRST CRETACEOUS PERIOD.

415. The great thickness of this stage, amounting at a mean estimate to 8000 feet, or above a mile and a half, shows that the duration of the period must have been considerable.

The composition of the stage includes the Purbeck beds, Hastings sand, Weald clay, and lower green sand of De la Beche, the Tilgate and Ashburnham beds of Mantell, and the Wealden or 15th group of Lyell.

The fauna, exclusive of Annulata, is presented in the following table:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the First Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	2	2	0	2	2
	Reptiles	11	5	6	9	5
	Fishes	14	1	13	4	0
Mollusca.	Cephalopods	15	7	8	1	1
	Gastropods	30	9	21	0	0
	Lamellibranchia	50	9	41	0	0
	Brachiopods	11	5	6	0	0
	Bryozoa	13	3	10	1	0
Radiata.	Echinodermata	21	10	11	3	2
	Polyparia	27	12	15	7	6
	Foraminifera	11	4	7	0	0
	Amorphozoa	8	3	5	4	2
		213	70	143	31	18

One genus of crustacea (Archæoniscus) being added, gives the total number of genera known as composing the fauna 214, of which 70 had not existed in any previous period.

The two genera of birds called Palæornis and Cimoliornis were webfooted, and were the first of the order which had yet appeared. The Archæoniscus was of the order of isopodous crustacea.

Independently of the other classes, the number of species of mollusca and radiata alone catalogued and described is 851. An example of the mollusca is given in fig. 15.

416. Among the reptiles of this period were two of monstrous size, the Iguanodon and Hylæosaurus. The former, which has taken its name from some remote resemblance to the Iguana, a land-lizard of intertropical countries, had a body as massive as that of the elephant, measuring, when full grown, about 30 feet in length. It was herbivorous, feeding on the foliage of the ferns, cicadeæ, and conifers, which constituted the flora of the period.

The Hylæosaurus, scarcely less in magnitude, was also an herbivorous reptile.*

Besides these, the coasts abounded in tortoises; and reptiles of nine other generic forms, including the last of that strange class of flying reptiles, the Pterodactyle, which never reappeared on the earth after this period.

417. The land was richly clothed with vegetation. A catalogue of the plants has been published by M. Brongniart, who observes that the generic vegetable forms were nearly the same as in the

* Mantell—Wonders of Geology—p. 437.

Jurassic age, the cicadeæ, however, being less numerous in relation to the ferns. The flora consisted principally of cryptogamous acrogenous plants, such as the arborescent ferns, the marsileaceous, and equisetaceous classes; of dicotyledonous gymnosperms, such as cicadeæ and conifers, and of many of doubtful classes.

SECOND CRETACEOUS PERIOD.

418. The composition of the second stage of the Cretaceous formation corresponds nearly with the 14th group of Lyell, including the Speeton clay of Yorkshire.

419. A generic summary of the fauna (excepting the Annulata), is given in the following table:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Second Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	0	0	0	0	0
	Fishes	3	1	2	0	0
Mollusca.	Cephalopods .	10	1	9	2	1
	Gastropods . .	12	1	11	0	0
	Lamellibranchia	31	0	31	0	0
	Brachiopods .	3	0	3	1	0
	Bryozoa . . .	3	0	3	0	0
Radiata.	Echinodermata .	2	1	1	0	0
	Polyparia . . .	4	2	2	2	2
	Foraminifera .	0	0	0	0	0
	Amorphozoa .	1	0	1	0	0
		69	6	63	5	3

420. The outlines of sea and land in Europe did not differ much from their configuration in the preceding period. An island was formed on the present site of the Alps, extending from Castellane near Digue, in the department of the Basses-Alpes, to the department of the Hautes-Alpes. See map, fig. 172.

421. The marine fauna differed but little from that of the preceding period, consisting of numerous cephalopods of singular forms (fig. 173, 174).

422. That the land was clothed with vegetation is proved by the numerous remains of wood found in the strata. M. Brongniart has described a pine of this period, the cone of which measured ten inches in length, and an inch and three quarters in diameter, found in the bed of the Marne near St. Didier.

423. The identity of the tropical species found in extremely different latitudes, as, for example, in France and at Magellan's straits, lead to the same inference, as in former periods, of the general prevalence of an equatorial climate at all parts of the globe.

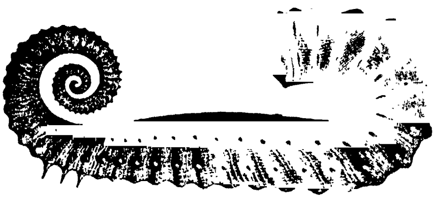


Fig. 173.—Ancyloceras Matheronianus.

Fig. 174.

424. The convulsion which closed this period was, according to M. D'Orbigny, that by which the Fuegian chain of mountains in South America, the direction of which was N. 30°. W. and S. 30° E., was raised.

THIRD CRETACEOUS PERIOD.

425. The deposit of this period corresponds with the 13th or gault group of Lyell, including the dark blue marl of Kent, the Folkestone marl or clay, and Blackdown beds and green sand and chert of Devon.

426. A view of the generic forms of the fauna is given in the following table:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Third Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	0	0	0	0	0
	Fishes	1	1	0	0	0
Mollusca.	Cephalopods .	11	0	11	1	0
	Gastropods . .	27	3	24	1	1
	Lamellibranchia	38	2	36	0	0
	Brachiopods .	6	0	6	0	0
	Bryozoa . . .	9	3	6	1	1
Radiata.	Echinodermata .	16	6	10	2	1
	Polyparia . . .	2	0	2	1	0
	Foraminifera .	9	2	7	0	0
	Amorphozoa .	4	1	3	0	0
		123	18	105	6	3

Adding two genera of Crustaceæ, the total number of generic forms in this period hitherto discovered amounts to 125, of which 20 were new, and 105 revived.

427. The outlines of land and sea were similar to those of the last period, except on the borders of the Anglo-Parisian basin between the departments of the Haute-Marne and Pas de Calais in France, which, hitherto uninvaded by the waters, were now submerged, which shows that the waters had advanced to the north in consequence of a subsidence of the ground in that quarter. The sea also extended to certain parts of the Eastern Pyrenees and the Var not previously submerged.

On the other hand, certain parts previously submerged were now dry land, as, for example, in the department of Vaucluse and along the line of the Alps from Escragnolles in the Var to Grenoble, all of which were covered by the sea of the previous period.

428. The seas were inhabited by fishes, Crustacea, and Mollusca,

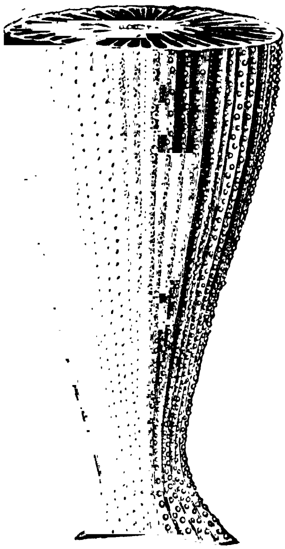


Fig. 175.—Cyathina Bowerbankii.

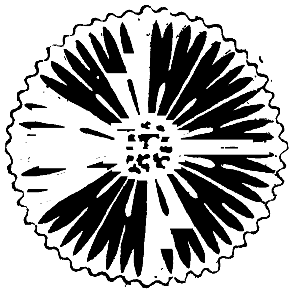


Fig. 176.

of numerous forms previously unknown. One of the Polyparia of this period is shown in figs. 175, 176.

No remains of terrestrial animals of this period have been found, and the only traces of vegetation are the remains of wood on the borders of the basins, with a few plants found at Lyme Regis and elsewhere.

429. Discordances in the strata indicate the convulsion which closed this period.

FOURTH CRETACEOUS PERIOD.

430. The fourth stage of the Cretaceous formation, called by M. D'Orbigny the Cenomanian, corresponds very nearly with the twelfth group, or upper green sand-stone of Lyell, including the Merstham fire-stone and the marly-stone, with chert of the Isle of Wight.

431. The generic forms of the fauna were as follow:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fourth Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles . . .	2	1	1	1	1
	Fishes	3	1	2	0	0
Mollusca.	Cephalopods .	10	1	9	1	0
	Gastropods . .	37	4	33	2	0
	Lamellibranchia	50	4	46	2	0
	Brachiopods .	11	1	10	2	0
	Bryozoa . . .	24	8	16	5	2
Radiata.	Echinodermata .	25	5	20	5	3
	Polyparia . . .	29	16	13	7	5
	Foraminifera .	14	7	7	3	3
	Amorphozoa .	18	6	12	2	1
		223	54	169	30	15

Among these a new genus of reptiles called the Raphiosaurus, and one of fishes called Otodus, were included.

432. The shores of the seas of this period underwent some changes, owing probably to a subsidence of the ground. They advanced in Belgium as far as Tournay. They covered also that extensive surface included between Fecamp and Tours, and between Tours and Bourges, submerging ground which had remained dry land since the close of the Jurassic age. They covered also the whole extent of the Pyrenean basin, from the department of the Loire Inférieure to that of the Lot, and from

thence to Spain and Portugal, which had hitherto remained dry land. In the Mediterranean basin the waters were limited to certain points, and from the prevalence of identical species of organic remains, it is probable that they extended in one direction without interruption to Mount Lebanon in Syria, and in the other into Germany, extending over Westphalia, Saxony, Silesia, and Bohemia.

The continents were somewhat extended on some of the borders of the basins, especially on the east of the Anglo-Paris basin in France, and upon its west in England; but they lost extent by the advancement of the sea, as already explained, in Belgium. The land was also diminished by the submersion of a large tract in the west of France, extending from the Loire to Havre.

433. The seas were animated by numerous fauna, consisting of fishes, new forms of Mollusca among the Gastropods and Lamellibranchia, and a great quantity of Brachiopods which formed extensive submarine banks. There were also innumerable varieties of Bryozoa, Echinodermata, and above all, of Polyparia. Of all the Cretaceous periods this was perhaps the most animated.

434. The shores of the seas were furnished with great varieties of marine plants—a catalogue of which with a description is due to M. Brongniart.

The terrestrial flora consisted principally of ferns, palms, cicadeæ, conifers, and dicotyledonous plants of uncertain families.

435. From what has been stated, it will be apparent that slow and local undulations of the ground, similar to what prevail at present in different parts of the earth, were common.

436. The convulsion which closed this period was that to which M. Elie de Beaumont ascribes the elevation of the system of Monte Viso (216), the direction of which is N.N.W. and S.S.E.

FIFTH CRETACEOUS PERIOD.

437. The fifth Cretaceous stage denominated Turonian by D'Orbigny, is identical with the eleventh or lower white chalk group of Lyell, including chalk without flints and chalk-marl. It is identical also with the upper plänerkalk of Saxony, and also with the chalk formation of Mantell.

438. The principal generic forms of the fauna of this period are shown in the following table:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fifth Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	0	0	0	0	0
	Fishes	0	0	0	0	0
Mollusca.	Cephalopods	5	0	5	1	0
	Gastropods	18	3	15	0	0
	Lamellibranchia	35	0	35	0	0
	Brachiopods	9	3	6	2	1
	Bryozoa	3	0	3	0	0
Radiata.	Echinodermata	11	1	10	4	0
	Polyparia	46	20	26	20	9
	Foraminifera	4	3	1	0	0
	Amorphozoa	4	1	3	1	1
		135	31	104	28	11

439. The outlines of the seas were nearly the same as in the former period; the shores, however, retired at several points, and especially in the Pyrenean basin, from the Loire Inférieure to La Vendée in the Mediterranean basin, upon all the known points, and in the chain of the Alps from La Malle in the department of the Var to Switzerland.

The continents underwent a corresponding change. The seas were very animated, as is evident from the vast number of Mollusca (fig. 14), and Echinodermata found upon the shores. They were also remarkable for numerous submarine reefs.

440. It would appear, from the fossil woods so frequently found, that the land was clothed with splendid vegetation, but owing to the destructive effects of the geological convulsion which followed, no complete remains either of plants or terrestrial animals have been found.

441. From the local absence of this fifth Cretaceous stage, it appears, that independently of several isolated points of land in France and Prussia during this period, a surface of dry land existed in Russia extending over 40° of longitude; another in North America measuring 30°; and others in South America and in India, which must have been above the surface of the waters, since no deposit corresponding with this stage appears there. Since all these regions were submerged in the succeeding period, it must be inferred that subsidence of the land over a great extent took place. This subsidence, according to M. D'Orbigny, extended from the torrid zone in the southern hemisphere to the 34° of latitude, and in the northern hemisphere to

the 56°, or over the immense extent of 90° of latitude, being a quarter of the terrestrial globe. In longitude this subsidence was not less extensive, and is assigned by M. D'Orbigny as the immediate cause which terminated the fifth Cretaceous period.

SIXTH CRETACEOUS PERIOD.

442. The sixth Cretaceous stage corresponds with the tenth or upper white-chalk group of Lyell, including the white chalk with flints of the north and south downs. It is identical with the strata called by the Italians la Scaglia.

443. A generic summary of the fauna is given in the following table:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Sixth Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	1	1	0	0	0
	Reptiles	5	3	2	1	1
	Fishes	41	24	17	22	15
Mollusca.	Cephalopods	12	0	12	10	0
	Gastropods	42	5	37	8	0
	Lamellibranchia	51	0	51	5	0
	Brachiopods	14	3	11	6	2
	Bryozoa	31	7	24	9	2
Radiata.	Echinodermata	34	11	23	19	6
	Polyparia	23	7	16	12	5
	Foraminifera	25	13	12	7	4
	Amorphozoa	24	7	17	21	6
		303	81	222	120	41

Adding two genera of Crustacea not included in this table, it appears that the fauna hitherto discovered consisted of 305 genera, of which 81 were new, and 224 revived from former periods.

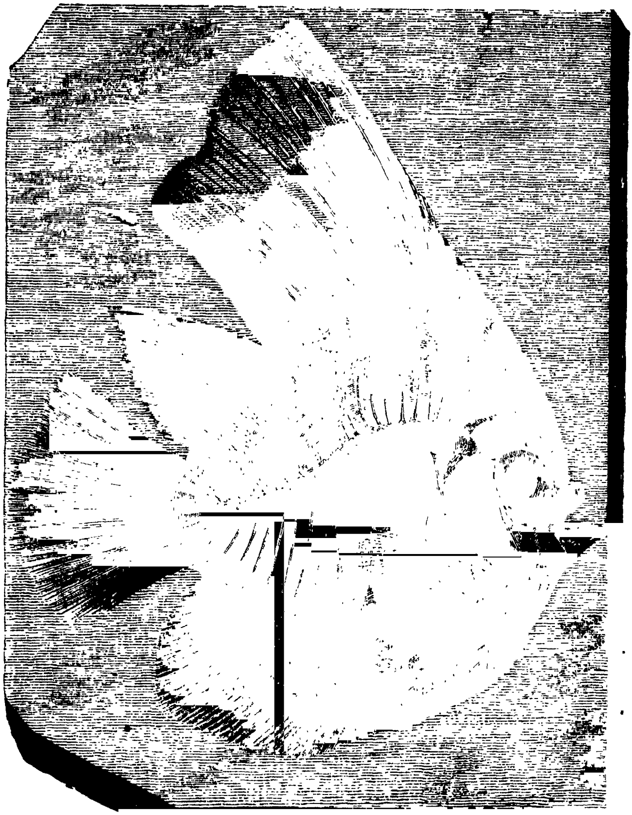


Fig. 184.—PLATAX ALTISSIMUS.

THE PRE-ADAMITE EARTH.

CHAPTER VIII.

444. First appearance of fishes similar to the salmon and perch—specific forms of Mollusca and Radiata.—445. Great duration of the sixth Cretaceous period.—446. Great changes in the outlines of land and water.—447. Specimens of the fauna.—448. Flora and land animals

—the Mosasaurus.—449. Close of the period. SEVENTH CRETACEOUS PERIOD: 450. Mineral character of the stage.—451. Synopsis of the animal kingdom.—452. Examples of the fauna.—**Tertiary Age.** 453. Origin of the name.—454. Classification of the strata—five stages—their nomenclature and thickness.—455. Complete series not found.—456. Section of the formation between the Vosges and Paris—discordances and isolation.—457. Palæontological distinction between the Tertiary and inferior formations.—458. The number of species in the Tertiary age.—459.—Distribution of the species among the stages.—460. General conclusions.—461. Outlines of land and water—D'Orbigny's map of France and England.—462. Great geographical changes from period to period.—463. Character of the fauna—great development of Mammifers.—464. Uniform prevalence of tropical climate.—465. Gradual and violent undulations of the land. FIRST TERTIARY PERIOD. 466. Mineral character of the stage.—467. Synopsis of the animal kingdom.—468. Great development of fishes.—469. Vast increase of land animals, including those of which the rhinoceros, otter, dog, ferret, and squirrel are types.—470. Creation of flat-fish.—471. The Mollusca—nummulites.—472. Whole mountains formed of these animals.—473. Vast duration of the period.—474. Terrestrial flora.—475. Outlines of land and water—Anglo-Parisian basin—form of its shores in France and England.—476. Pyrenean basin.—477. Mediterranean basin.—478. Its great extent towards the east.—479. Fresh-water lakes.—480. Close of the period. SECOND TERTIARY PERIOD. 481. Elevation of the Pyrenees—elevation of the tract of Bray in France, and of the Wealden in England.—482. Synopsis of the animal kingdom.—483. Specific forms of Mollusca and Radiata.—484. Creation of Cetacea, or whale forms.—485. Prodigious numbers of Miliolæ, of which the stone quarries of Paris are formed.—486. Marine flora—land animals, including the generic forms of which apes, bats, gallinaceous, predaceous, and climbing birds, serpents, rattle-snakes, baboons, and opossums are types.—487. Crocodiles and land tortoises—belemnites and nautili—terrestrial flora.—488. Outlines of land and water—division of Anglo-Parisian basin into two seas.

444. THIS period was signalised by the first appearance of fishes of the Cycloid and Ctenoid orders (salmon and perch), and also by numerous genera of Foraminifera. The number of species of Mollusca and Radiata alone which entered into the composition of this fauna was 1577, all of which were new to animated nature, and all of which disappeared at the close of this period.

445. The great thickness of the stage, measuring, as we have seen, 1000 feet, and the great number of species found in it, lead to the conclusion that this sixth period was one of the longest of the Cretaceous age.

446. The seas of this period underwent considerable changes both in France and England. In some parts their shores retired, leaving increased tracts of dry land, while in others, as in the department of La Manche in France, tracts hitherto dry were

submerged. Great changes were also produced at other points. Thus it was at the commencement of this period, that in consequence of a considerable subsidence of the land, the sea flowed over all Belgium as far as Maestricht, covering land which had remained dry since the close of the Palæozoic age. It was also during this period that the sea extended its limits from Snowdon to the Ural Mountains, over an extent of 40° of longitude. It also covered a surface of 30° upon the southern coast of South America. It covered also Chili in the western continent, and Pondicherry in the eastern. From the identity of the marine deposits, it may be inferred that the sea of this period extended without interruption from France to all those distant points and from the tropics to the 56° north, and the 34° of south latitude.

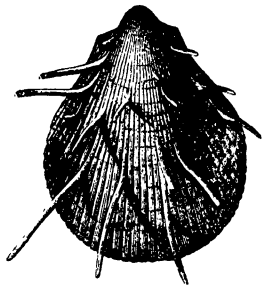


Fig. 177.—Spondylus spinosus.

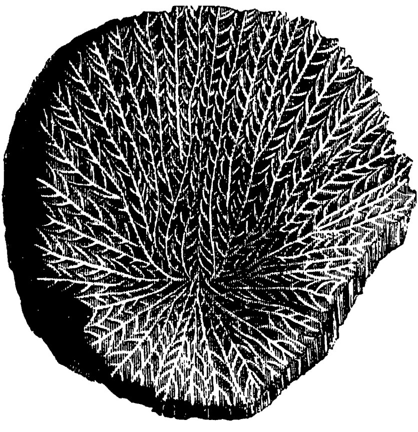


Fig. 178.—Reticulopora obliqua.

The land underwent changes corresponding with those of the seas, being everywhere augmented where the seas retired, and diminished where they advanced.

447. The Cycloid and Ganoid fishes prevailed in great numbers

in the seas, which were also animated by an infinite variety of Mollusca—Gastropods, Brachiopods, Lamellibranchia (fig. 177), and Bryozoa (fig. 178).

448. The shores of the seas were abundantly furnished with marine vegetables. Of terrestrial animals, one genus of birds, called Scolopax, has been found: and of land reptiles, two genera, Leidon and Mosasaurus. The jaws of the latter are shown in fig. 179.

449. The geological convulsion which terminated this period,

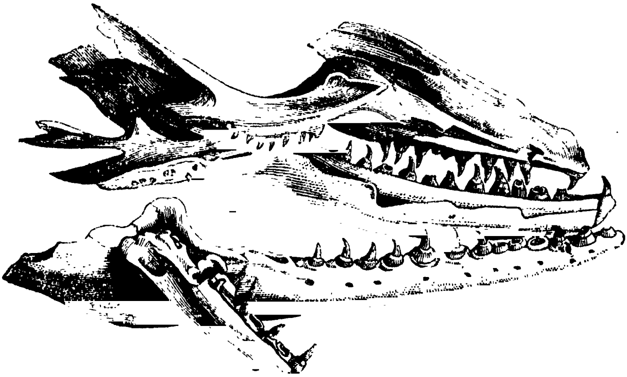


Fig. 179.—Mosasaurus Camperi.

according to M. D'Orbigny, was that which raised the chain of the Cordilleras of Chili, the direction of which is N. 5°. E. and S. 5°. W.

SEVENTH CRETACEOUS PERIOD.

450. In every point of view, this is the least important of the periods, being the last stage of the decadence of the Cretaceous age. This stage has no representative in the British strata. It is identified by Sir C. Lyell with the Maestricht beds, a group of strata observed near that city, on the banks of the Meuse, having the thickness of about 100 feet. It rests upon the ordinary white chalk and flints, which form the sixth Cretaceous stage, and contains fossils, which, according to Sir C. Lyell, are, on the whole, very peculiar, and all distinct from those of the Tertiary age, which immediately succeeded it.

451. The following is a general view of the fauna of this period, so far as the fossil remains show it.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Seventh Cretaceous Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	0	0	0	0	0
	Birds	0	0	0	0	0
	Reptiles	1	0	1	1	0
	Fishes	?	?	?	?	?
Mollusca.	Cephalopods	2	0	2	1	0
	Gastropods	17	1	16	0	0
	Lamellibranchia	11	0	11	0	0
	Brachiopods	2	0	2	1	0
	Bryozoa	0	0	0	0	0
Radiata.	Echinodermata	4	1	3	1	0
	Polyparia	8	0	8	5	0
	Foraminifera	0	0	0	0	0
	Amorphozoa	1	0	1	0	0
		46	2	44	9	0

452. Independently of some Saurians, fishes, Crustacea and Annelides, found among the fossils, sixty-six species of Mollusca and Radiata have been catalogued by M. D'Orbigny, of which only two are common to this and the preceding period. Of these, a considerable number, including the Nautilus Danicus (figs. 9, 10, 11), are found in this stage in Sweden as well as in France, and may be regarded as more especially characteristic of the closing period of the Cretaceous age.

The Tertiary Age.

453. At an early date in the progress of the science, the strata below the Jurassic formation were called primary, and the Jurassic and Cretaceous formations, taken together, were denominated secondary, having been obviously deposited from the seas of that era upon the former. Hence the most recently deposited group of strata resting upon the Cretaceous formation, and immediately subjacent to the diluvial and alluvial deposits of the human period, received the name of Tertiary, which, by general consent, they have retained, although subsequent discoveries have shown that the preceding deposits, instead of being resolved into two, are much more properly regarded as consisting of a greater number of distinct groups.

454. The strata composing the Tertiary formation have been very variously classed, and grouped in geological works. Sir Charles Lyell has divided them into three principal groups, which

he calls Eocene, Miocene, and Pliocene. He divides the first into three, and the last into two subordinate groups, thus making the whole formation consist of six stages. M. D'Orbigny finds that a division into five stages is more in accordance with the distribution of the organic remains. The following are the names which he has given to the five strata, with their origin, and their estimated average thickness:—

No. of stage.	Name.	Origin.	Thickness.
V.	Sub-Apennine	Apennines . . .	Feet 2000
IV.	Falunian . .	Falun (conchiferous crag)	1000
III.	Tongrian . .	Tongres	330
II.	Parisian . .	Paris	3300
I.	Suessonian or Nummulitic .	Soissons	3300
		Total . . .	9930

Although these estimates of thickness must be regarded as mere approximations, they will, nevertheless, be useful as exponents of the relative duration of the five periods into which the Tertiary age is divided. The total average thickness of this Tertiary formation would appear to be about 10000 feet, or two miles, the chief parts being occupied by the two lowest stages.

455. The complete series of stages can scarcely be found in any single locality, but, partially united, their order can be easily determined by comparing sections made in different places.

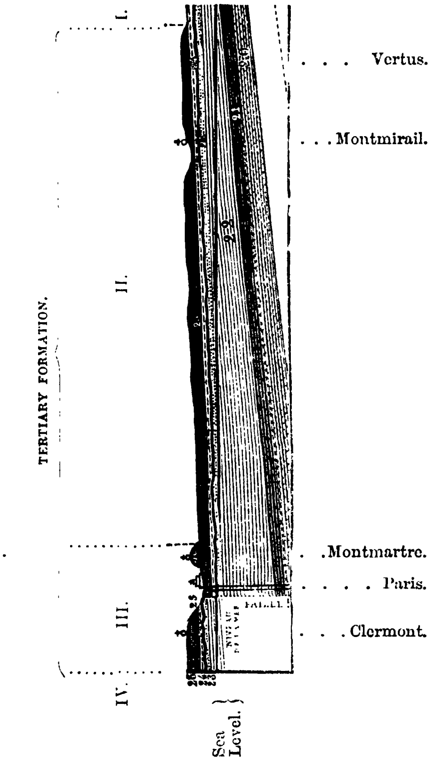
456. Fig. 180 represents a section from Vertus to Paris, being the continuation of the general section of the country from the Vosges to Paris, the first three divisions of which, commencing from the Vosges, have been already given in figs. 141, 152, and 170. In this section, the first three only of the stages, proceeding upwards, are included, being numbered 24, 25, and 26.

As in the preceding formations, the single stages are distinguished one from another, partly by discordance of stratification, but much more by what geologists call discordances of isolation; that is, by the appearance of certain stages, and the absence of others. For example, while round the Anglo-Parisian basin the first of the Tertiary stages is deposited immediately upon the last of the Cretaceous; in other places many intermediate stages are wanting. Thus, near Orgon, in France, the first Tertiary stage is deposited upon the first Cretaceous, all the other six stages of the Cretaceous formation being absent. In like manner, in the department of the Aude, the first Tertiary stage is deposited upon the Palæozoic formation; and in the department of the Var and the Lower Alps upon the Jurassic formation. In

like manner, throughout the province of Touraine, the first and second Tertiary stages are absent, the third being deposited in different localities upon the Azoic, Palæozoic, the Jurassic, or the Cretaceous formations.

457. Palæontological considerations supply other distinctions between the Tertiary and inferior formations. Nearly 230

Fig. 180.



generic forms extinct at the close of the Cretaceous age, and not appearing in the Tertiary age, constitute a distinguishing characteristic between the two epochs. In like manner, at the commencement of the human period, 1324 new generic forms were created which had no previous existence, and which, not being present in the Tertiary age, supply a distinction between it and the human epoch.

458. The number of species of plants and animals of every order which lived in the Tertiary age, greatly exceeds that of any former period. The number of vegetable species found in the Tertiary strata exceeds 600, and that of Vertebrata and Annulata amounts to nearly 1500, while the number of Mollusca and Radiata, catalogued and described as belonging to this age, amounts to 6042.*

459. The proportion in which this vast number of specific forms of Mollusca and Radiata are distributed through the five Tertiary stages is as follows:—

Stages.	No. in two or more stages.	No. limited to each stage.	Totals.
I.	8	670	678
II.	8	1568	1576
III.	0	428	428
IV.	28	2726	2754
V.	83	523	606
	127	5915	6042

The same species being repeated in the second column, a corresponding deduction of the total number from the common species must be made, which will reduce the actual number of the common species to ninety-one, which is equivalent to 1½ per cent. of the total number.

460. From this and other observations made upon the strata composing the Tertiary formation, the following conclusions have been adduced:—

1°. That there existed in the Tertiary age above 8000 species of animals, altogether distinct from those of the preceding and following ages, and which, therefore, are characteristic of the Tertiary age.

2°. That this total number consisted of five distinct groups, which existed severally during the five periods of the Tertiary age, their remains being deposited in the five superposed stages composing the Tertiary formation.

3°. That each period therefore had its own special fauna, having nothing in common with those of the preceding or succeeding periods.

4°. That the species which, owing to accidental causes or erroneous designations, have been found in two or more stages, the number of which has been greatly overrated, do not in reality exceed 1½ per cent. of the total number of species discovered.

461. The seas of this age in Western Europe consisted of four,

* Prodrome D'Orbigny, vols. ii. and iii.

three of which, the Anglo-Parisian, the Pyrenean, and the Mediterranean basins correspond with those of former epochs.

Fig. 181.—Map of France and England in the Tertiary Age. By M. D'Orbigny.

The fourth, to which the name of Ligerian basin has been given, covered part of the western provinces of France, as indicated upon the map (fig. 181).

462. It must not be understood, however, that during the whole continuance of the Tertiary age, or even during any two periods of it, these seas maintained the same circumscription or corresponded exactly with the outlines given in this map. On the contrary, the geological convulsions which took place between period and period, produced such changes of level in the land as completely to derange the outlines of land and water. Thus the Anglo-Parisian basin not only changed its form and limits in different periods, but in one totally disappeared, while in the first periods of the Tertiary age the Ligerian basin had no existence. Previously to the convulsion in which the chain of the Pyrenees was elevated, the Pyrenean basin covered the ground upon which that range afterwards stood, but after their elevation its shores were driven northwards and its dimensions considerably reduced. These changes of the outlines of land and water will, however, be more clearly explained in the account we shall give of the successive periods of this age.

463. The most striking characteristic of the fauna of the Tertiary age, was the extraordinary development which took place among vertebrated animals. It was then indeed that the land was first peopled by those mammifers so remarkable for their proportions and characters, such as the Anthracotheriums, the Palæotheriums, the Anoplotheriums (fig. 182), the Dinotheriums, the Toxodons, the Mastodons, the Smilodons, the Glyptodons (fig. 183), the Megatheriums, the Megalonix, and many others. It was then also that the continents were first peopled by birds which would be pronounced colossal even beside the ostrich, and with salamanders as large as the present crocodile. Around this stupendous fauna was collected a flora on a proportionate scale. The seas were peopled by marine classes in a corresponding proportion, and almost as varied as in our own day.

464. The generic animal forms, peculiar to present tropical climates, being found distributed indifferently in all latitudes, it is inferred that a general tropical temperature, as in former periods, prevailed, and that consequently no isothermal lines or climatological distinctions existed upon the earth until the present period.

465. Numerous indications are also found among the geological phenomena, of the prevalence during this age of those slow and gradual undulations of the earth's crust which are still in progress in the north of Europe and elsewhere, independently of the more violent class of convulsions by which period was divided from period, fauna from fauna, and flora from flora.

FIRST TERTIARY PERIOD.

466. The first Tertiary stage in its mineralogical characters corresponds with the lower part of the Eocene group of Lyell, the Nummulitic formation of Gras and other geologists, the Plastic clay of Dufresnoy, Elie de Beaumont, and Mantell, and the Woolwich sands of Morris.

467. After the general agitation produced by the geological convulsion which closed the Cretaceous age had subsided, a new fauna and flora were called into existence to people and clothe the earth. A generic synopsis of the former is produced in the following table:—

Synopsis of the Animal Kingdom (exclusive of Annulata) during the First Tertiary Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	6	6	0	0	0
	Birds	1	1	0	1	1
	Reptiles	2	0	2	0	0
	Fishes	91	83	8	34	34
Mollusca.	Cephalopods	3	2	1	0	0
	Gastropods	70	34	36	0	0
	Lamellibranchia	35	5	30	1	1
	Brachiopods	2	0	2	0	0
	Bryozoa	10	0	10	1	0
Radiata.	Echinodermata	23	13	10	4	3
	Polyparia	17	8	9	3	1
	Foraminifera	8	3	5	0	0
	Amorphozoa	1	0	1	1	0
		269	155	114	45	40

With the addition of one genera of Crustacea (squilla), the total summary of the generic forms of animal life in this period will then be 270, of which 156 were now first created, and the remaining 114 revived from former periods.

468. This period was remarkable for the great development of fishes, of which 83 new genera were created. Of the Mollusca, the Gastropods were most developed, 34 new genera having appeared. The total number of species of Mollusca and Radiata described in this period amounts to 678, which, however numerous, are inferior in number to the same divisions in some former periods. Before the Tertiary age, some few traces of the existence of Mammifers were found, but with the exception of a few isolated bones, such traces everywhere consisted of foot-tracks.

469. The commencement of the Tertiary age was, however, more especially signalised by a prodigious accession to this highest

branch of the animal kingdom, six genera being created and named as follows:—

Anthracotherium, a genera of Pachydermatous animals, found in the lignite or brown coal in Italy, the name being a Greek compound, signifying *coal beast.*

Lophiodon, another Pachydermatous animal, allied to the Rhinoceros or Tapir, taking its name from a Greek compound, signifying *teeth*, formed like the hairs of a *mane.*

Lutra, a generic form of which the otter is the type.

Canis, a generic form of which the dog is the type.

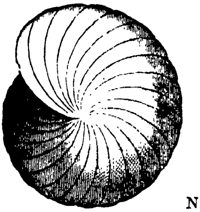
Viverra, a generic form of which the ferret is the type.

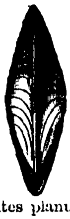
Sciurus, a generic form of which the squirrel is the type.

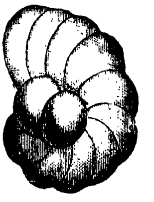
470. The seas were enriched with a great number of animals hitherto unknown. The shores were animated by innumerable fishes, including many Pleuronectoids, or flat fish, which now appeared for the first time (fig. 184).

471. Among the multitude of Mollusca new to the world at this epoch, may be mentioned the Beloptera, Oliva, Tritons, Terebratulæ, &c. The Zoophytes and Foraminifera abounded, compensating by their prodigious numbers for the minuteness of their dimensions; but the class from which the period took its most prominent character was that of the Nummulites, an animal of a round flat form, resembling that of a coin, from which the name of the class is taken (figs. 185, 186, 187). These animals are technically described as chambered spiral univalve shells.

Fig. 185. Fig. 186. Fig. 187.







Nummulites planulata.

These Nummulites lived far from the coast, and their shells were deposited in layers of prodigious thickness upon the deepest bottoms of the seas.

472. At subsequent periods geological convulsions occurred, by which the conchiferous strata thus formed were forced upwards, so as to form mountain ranges. An example of such chains is presented in the Pyrenees, where entire mountains are found consisting of little else than the fossilised remains of these minute animals. It is a striking fact also, that it was of like materials that the Pyramids of Egypt were built.

473. The great duration of this first Tertiary period may be judged from the fact, that these nummulitic strata have in some localities a thickness of several hundred yards. The marine flora of this period consisted chiefly of Cryptogamous Amphigenes, Algæ, and monocotyledonous Naiads.

474. The terrestrial flora consisted of Cryptogamous Acrogenes, such as Hepaticæ, ferns, Equisetaceæ or mares' tails, Characeæ, Palms, Conifers, and Taxineæ.

475. In comparing the geography of this period with that of the preceding, it will be seen that, while at some parts the seas are limited by the same shores, at others their outline is completely changed. Upon the northern and southern borders of the Anglo-Parisian basin, the shores lie within those of the Cretaceous age, leaving a band of ground, previously submerged, uncovered. On the south, the shores have retired still further, no traces of the deposits of this stage being found beyond the line which would pass through Montereau, Melun, Paris, Houdan, and Louviers. This basin extended in England, in an irregular direction S.W. and N.E., from Dorchester to Wells, passing through Dorsetshire, Wiltshire, Surrey, Berkshire, and Hertfordshire, in a direction which probably extended much further to the north over the ground now covered by the German Ocean.

476. In the Pyrenean basin the northern limits of the sea were nearly the same as in the Cretaceous period. It extended probably from the Atlantic Ocean to the Mediterranean, covering all the space upon which the Pyrenees now stand as well as part of Spain.

477. In the Mediterranean basin the sea entirely changed its place: Provence, which it formerly covered, was now occupied by fresh-water lakes, but the sea appeared above Grasse, in the department of the Var; its western shore extended W.N.W. to Castellane, and seemed to follow the line now occupied by the chain of the Alps to Annecy, and beyond that to Glaris.

478. Beyond these limits this sea extended to the east, over Sardinia, Italy, the Tyrol, part of Switzerland, and communicated probably with Egypt, the Crimea, the Caucasus, and from the slopes of the Ural to India. Corresponding changes took place on the land, a fresh-water lake existed at Rilly la Montaigne. On the north of the Pyrenean basin the land was uninterrupted from the Ocean to the Mediterranean.

479. A fresh-water lake covered the part of Provence between Orgon, Martignes, and Aix. These and other details may be easily followed on M. d'Orbigny's map (fig. 181), where the seas of this period are distinguished by the shading number 24.

480. The changes which took place in the outlines of land and water in consequence of the convulsion which closed the Cretaceous

age, and which preceded the first Tertiary period, will be clearly perceived by comparing those parts of the map (fig. 181), which we have here indicated, with the parts of the map (fig. 172, numbered 22.)

SECOND TERTIARY PERIOD.

481. The animal and vegetable world of the first period was swept away by the convulsion produced by the elevation of the chain of the Pyrenees, which was attended with a general perturbation of the whole surface of the globe. The date of this convulsion is identified with the first Tertiary period by the fact of the nummulitic strata which were deposited during that period being found dislocated along the entire extent of the Pyrenean range. The same dislocation elevated the tract of Bray in France and the country round Boulogne, both of which were submerged by the Anglo-Parisian sea. Parts of Surrey and Sussex in England, including the Wealden, were raised at the same time.

The second Tertiary stage includes the London clay of English geologists, the fresh-water and marine formation of Morris, a part of the eocene of Lyell, the blue clay of Bracklesham, the arenaceous limestone of Bognor of Mantell, and the calcareo-arenaceous system of Galeotti.

482. The following is the generic synopsis of this period:

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Second Tertiary Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	21	17	4	8	7
	Birds	11	10	1	2	2
	Reptiles	6	2	4	0	0
	Fishes	39	20	19	14	10
Mollusca.	Cephalopods	4	0	4	1	0
	Gastropods	78	7	71	6	1
	Lamellibranchia	57	9	48	3	3
	Brachiopods	2	0	2	0	0
	Bryozoa	14	1	13	2	1
Radiata.	Echinodermata	18	5	13	6	3
	Polyparia	45	28	17	20	16
	Foraminifera	31	13	18	5	3
	Amorphozoa	1	0	1	0	0
		327	112	215	67	46

With the addition of five genera of Crustacea, the total number of genera ascertained to have existed in this period was, therefore, 332, of which 116 appeared for the first time in the world.

483. Independently of several hundred species of Vertebrata and Annulata, the fauna of this period included 1576 species of Mollusca and Radiata, which have been enumerated and described by D'Orbigny.

484. A great number of new animals abounded in the seas, the chief part of which consisted of new genera of fishes and Polyparia or Zoophytes. It was in this period that the class of Cetacea or marine mammifers first appeared in the genera of the Dolphin and the Balænodon. Among the Crustacea the generic forms of crabs were first presented.

485. Of the Zoophytes and Foraminifera, the Miliolæ, characterised by its multilocular shell, and taking its name from *milium*, the Latin word for millet seed, prevailed in numbers so enormous, as to form those strata of stone of which nearly the whole of the city of Paris is built. It is a curious circumstance, therefore, that one of the greatest cities of the world should owe its fabrication to the original industry of minute animals which lived countless ages before the creation of man. The prodigious multitude of these minute beings, which must have existed to produce the quarries of Paris alone, not to mention similar ones which exist elsewhere, may be imagined when it is stated that, taking into account the weight of these shells, it has been calculated that a cubic inch of stone must be composed of not less than two thousand millions of them.

486. The marine flora of this period was generically similar to that of the last, differing, however, altogether in the species. Numerous land animals appeared for the first time, among which may be mentioned the following,—*mammifers*, apes and bats; *birds* (fig. 188), predaceous climbers and gallinaceous; *reptiles*,

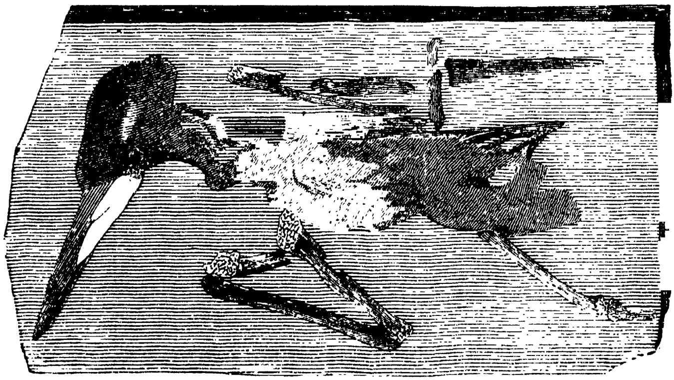


Fig. 188.—Fossil in the Gypsum of Montmartre.

serpents. The forests of France and England abounded in generic forms, of which baboons, rattlesnakes, and opossums are the living types.

The plains nourished Pachydermatous animals, called Paleotherium, Anaplotherium, &c. (fig. 189).

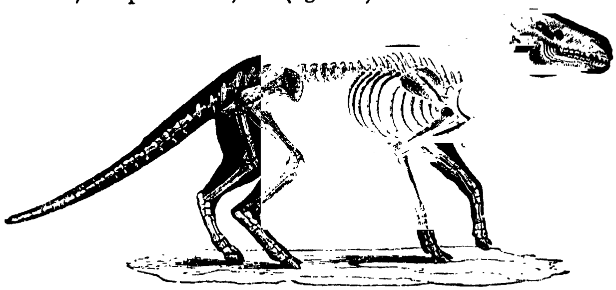


Fig. 189.—Common Anaplotherium.

487. The gigantic saurians of former periods had altogether disappeared in the Cretaceous age, but a large race of crocodiles and land and sea tortoises succeeded them. The Belemnites and their chambered shells had disappeared from the seas, the Nautilus alone remaining.

The cicadeæ totally disappeared from the flora, and new conifers, with dicotyledonous plants and palms, appeared in the centre of Europe,—plants which at present have receded into Africa, showing that the mean temperature of the continent then corresponded to that which at present prevails in Lower Egypt.

488. The outlines of land and water underwent important changes in consequence of the convulsions which preceded this period. The Anglo-Parisian basin was divided into two gulfs, completely separated, by a tract passing through its middle in a direction nearly east and west. The two separate basins thus formed are marked on the map by the shading 25. The northern basin in France covered part of Belgium, including Brussels and Ghent, with an angle of France, which included Dunkirk. In England it included London and the mouths of the Thames.

The southern basin was limited in France on the north by Laon, and extended east and west between Havre and Epernay, being bounded by an irregular line. It may be considered as highly probable, if not certain, that the northern gulfs in England and France communicated with each other by a tract of water included within the dotted lines on the map, and that in like manner the southern gulfs were united by a tract of water extending from Havre to the Isle of Wight.

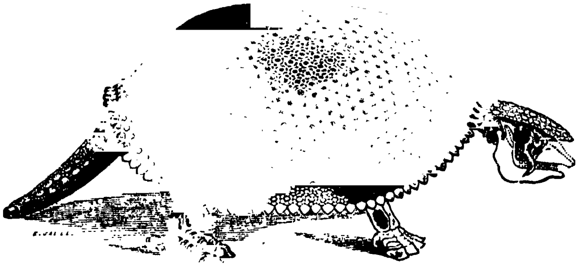


Fig. 183.—GLYPTODON CLAVIPES.

THE PRE-ADAMITE EARTH.

CHAPTER IX.

489—490. Great change in the Pyrenean and Mediterranean basins.—491. Land and water in the United States.—492. Effect of the elevation of the Pyrenees.—493. General prevalence of tropical climate.—494. Great change in the Mediterranean basin.—495. Sketch of part of Western Europe by Elie de Beaumont. THIRD TERTIARY PERIOD. 496. Mineral character of the stage.—497. Convulsion which preceded the period.—498. Outlines of land and water.—499. Marine fauna and specific forms of Mollusca and Radiata. FOURTH TERTIARY PERIOD. 500. Mineral character of the stage.—501. Synopsis of animal kingdom.—502. Specific forms of Mollusca and Radiata.—503. Convulsion which preceded the period—Disappearance of Anglo-Parisian sea—Ligerian basin.—504. Pyrenean basin.—505. Marine fauna.—506. Enormous increase of land animals, including the generic forms of the bear, the cat, the weasel, the seal, the mouse, the beaver, the rhinoceros, the tapir, and the stag.—507. Great increase of reptiles and fishes, including snakes, frogs, salamanders, perch, herring, and carp.—508. Flora, including the generic forms of various conifers; birch, alder, oak, beech, elm, fig, plantain, poplar, laurel, sloe-tree, maple, red jasmin, madder.—509. Uniform tropical climate. FIFTH TERTIARY PERIOD. 510. Mineral character of the stage.—511. Synopsis of the animal kingdom.—512. Outlines of land and water.—513. Elevation of the Western Alps—its effects.—514. Map of France by M. Elie de Beaumont.—515. Marine animals, including the generic forms of gudgeon, pike, loach, blay, and tench.—516. Terrestrial fauna including the megatherium, megalonyx, mylodon, and mastodon, and the generic forms of the elephant, hippopotamus, camel, giraffe, and stag.—517. Birds of the generic forms of the vulture, eagle, swallow, woodpecker, chat, anabate, lark, mothhunter, cuckoo, parrot, pheasant, common fowl,

guinea fowl, flamingo, horned owl, rail, corncrake, goose, loon, duck, gull, &c.—518. Fossil salamander of Œningen.—519. Flora, including generic forms of liquidamber, willow, myrtle, anemone, plum-tree, magnolia, holly, rhododendron, and azalea.—520. Large numbers of Mammifers. —521. Bone caves—cave of Gaylenreuth.—522. Retrospect. — 523. Was creation at each period simultaneous. — 524. Proofs in the affirmative.—525. Was there a progressively increasing perfection of organisation.—526. Number of orders in the respective strata.—527. Of genera in the orders.—528. Increase and decrease of genera in the orders.—529. Orders in which the decrease took place.—530. Orders of fishes.

489. GREATER changes still were produced, as indeed might be expected, in the Pyrenean basin. While its northern shores remained nearly the same, the southern limits were altogether changed. The sea, which in the preceding period covered all the ground upon which the Pyrenees stand, extending over part of Spain, was now driven back to the north, and occupied only a very small basin near Bordeaux, marked 25 on the map.

490. The same cause produced a considerable change in the shores of the Mediterranean basin, which no longer communicated with the Pyrenean basin, its western shores being driven back towards the east. It is probable that its western shores commenced near Nice, passing near Faudon and St. Bonnet, the site of the High Alps, from which, however, that chain had not yet arisen. From thence the shores of this sea were continued to Bex in Switzerland, where all traces of them are lost.

491. During this period, a considerable tract of the United States, extending from 31° to 39° lat., which had been raised above the waters since the end of the Cretaceous age, became submerged, so that the sea probably extended without interruption from Paris to the southern part of North America.

492. Corresponding changes took place in the land by the elevation of the chain of the Pyrenees, which presented a barrier to the progress of the ocean, and which left high and dry not only the mountain range itself, but also the interval included between that and the central plateau of France, so that Languedoc and Provence, and the surrounding country, formed one great continent.

493. The appearance of marine species identical with those deposited in the Anglo-Parisian basin in the seas by which the southern states of America were submerged, and the discovery of apes, rattlesnakes, and generic forms of marine animals and plants, proper to warm climates in all parts of Europe, and in the Isle of Sheppey, in England, prove that, at this epoch,

the temperature of the present equatorial regions prevailed generally throughout Europe.

494. During this period, the Mediterranean basin was reduced to some small patches of water, which appeared in the Savoy, and in the region upon which the French Alps now stand. These are marked upon the map by the number 25.

495. Before the geology of Western Europe, in relation to this age, was submitted to the elaborate analysis of M. D'Orbigny, from which the details explained above have resulted, M. Elie de Beaumont published a map of its geography during this period, of which we give a reduction in fig. 190.

It will be seen that, according to this, the Anglo-Parisian

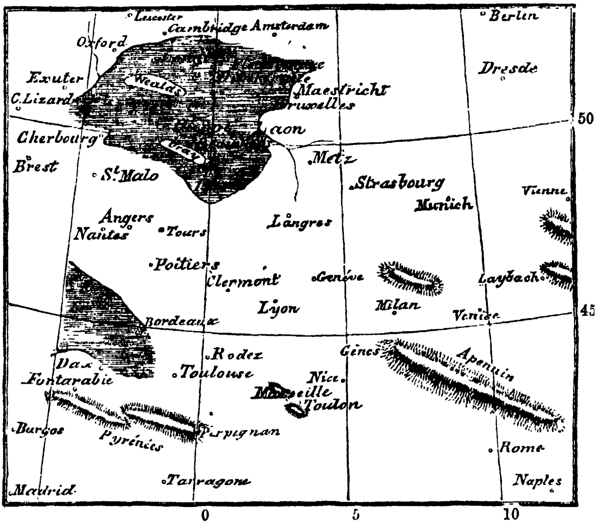


Fig. 190.—Map of Western Europe during the Second Tertiary Period.

basin was not inferred to be divided into two separate gulfs, as above described, but an insular tract was supposed to be formed around the country of Bray in France, and another around the Wealden in England.

The basin was assumed by M. Elie de Beaumont to extend between Paris and the Lizard Point, Cambridge and Maestricht. The Pyrenean basin is represented as limited between Bordeaux and Dax. It is probable, however, that the more recent

geological researches in these regions have supplied data which have rendered the map of M. D'Orbigny the more exact.

THIRD TERTIARY PERIOD.

496. The strata deposited during this period, according to M. D'Orbigny, correspond with the middle *terrain tertiaire* and *grès de Fontainebleau* of MM. Dufresnoy and Élie de Beaumont, the Tongrian, Rupelian, and Bolderberg strata of M. Dumont, the Molasse of Switzerland, the Faluns bleus of M. Grataloup, and, in fine, with the fifth group of M. D'Archiac.

497. The second Tertiary period was closed by the convulsion which raised the system of Corsica and Sardinia of M. Elie de Beaumont. Upon the re-establishment of tranquillity, a new fauna was created, consisting of 428 species of Mollusca and Radiata, independently of the vertebrated and annulated classes.

498. The outlines of land and sea underwent several changes, the results of which will be seen on the map, the seas during this period being indicated by the shading marked 26*a*, fig. 181. The Paris basin was limited to a space round Paris, between Provins and Evreux, east and west. The Pyrenean basin covered the space similarly indicated and shaded, a tract of dry land, however, remaining to the N.W. of Blay. In Belgium, the seas advanced to the N.E., as far as Limbourg, in the neighbourhood of Maestricht.

499. The marine animals of this period, though generically identical with those of the succeeding one, were, nevertheless, specifically distinguished from them. This distinction has not, however, been clearly indicated, except in the case of the Mollusca and Radiata, 428 species of which M. D'Orbigny has identified with the deposits of this period. The flora included nearly the same generic forms as in the preceding epoch.

FOURTH TERTIARY PERIOD.

500. The strata deposited in this period, according to D'Orbigny, include part of the middle Tertiary and Falunian of MM. Dufresnoy and De Beaumont, the Molasse, Falunian and Crag of M. Cordier, the superior order of Conybeare, and the Miocene and Suffolk and Norfolk Crag of Sir C. Lyell.

501. The following is the generic summary of the fauna, which, however, includes a certain number of genera of the Vertebrates peculiar to the third stage.

FOURTH TERTIARY PERIOD.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fourth Tertiary Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers	57	47	10	27	23
	Birds	7	4	3	0	0
	Reptiles	13	7	6	3	2
	Fishes	28	7	21	1	1
Mollusca.	Cephalopods	3	1	2	2	1
	Gastropods	97	20	77	1	1
	Lamellibranchia	64	6	58	2	0
	Brachiopods	8	1	7	0	0
	Bryozoa	20	5	15	3	2
Radiata.	Echinodermata	23	6	17	2	1
	Polyparia	45	15	30	16	6
	Foraminifera	42	14	28	3	2
	Amorphozoa	1	0	1	0	0
		408	133	275	60	39

With the addition of fourteen genera of Crustacea, it appears, therefore, that this fauna consisted of 422 genera, of which 133 were new, and the remainder revived from preceding periods.

502. Independently of several hundred species of Vertebrata and Annulata, 2754 species of Mollusca and Radiata proper to this period have been catalogued and described.*

503. The third period was closed, and the present preceded by the dislocation which produced the system of the Isle of Wight, of the Tatra, of the Rilodagh, and of Mount Hæmus, as shown by M. Élie de Beaumont. After the re-establishment of tranquillity, the outlines of sea and land had undergone considerable changes. The water by which the Anglo-Parisian basin had never ceased to be submerged since the Triassic age, retired, and left all that region dry land. A new sea, however, was formed in the west of France, to which the name of the Ligerian basin has been given by M. D'Orbigny, and the limits of which are indicated on the map by the shading marked 26 *b*, fig. 181. The deposit left by this basin was, however, by a subsequent convulsion, broken into patches, so that, at the present time, it does not present one continuous stratum.

504. The Pyrenean basin was contracted within the limits marked on the map 26 *b*, fig. 181. The Mediterranean basin under-

* Prodrome D'Orbigny, vol. iii. p. 25 *et seq.*

went a complete change of form. It now submerged a vast surface, which was previously dry land, included between Montpelier and a tract to the west of Marseilles, extending on the north into the departments of the Gard and the Drôme. It extended also to the N.E. as far as the tract upon which the Lower Alps stand. Another arm of this sea turned to the N.N.E., covering part of Savoy and Switzerland, and extending probably to Vienna and still further in that direction. Thus three seas were still found in the west of Europe—the Ligerian basin taking the place of the Anglo-Parisian basin. In England, the Anglo-Parisian basin was limited to Suffolk and Norfolk, where it covered the whole coast, and it probably extended from thence across the Channel into Belgium, covering the land around Antwerp.

505. The seas during this period were peopled by numerous animals unknown to any anterior epoch. Not less than 89 marine genera appeared for the first time, among which the Gastropods amounted to 20, and the Foraminifera to 15. Among the Crustacea which now first appeared in the seas, were included the generic forms of which the Hermit crab and the Lobster are types.

506. But it was by its land animals that this period, compared with all former ones, was more especially remarkable. It appears by the table, that of the 57 genera of Mammifers ascertained to have lived in this period, 47 had never before existed. Of these genera a great number, remarkable either for their magnitude or their peculiar forms, have become extinct, among which may be mentioned Palæomys, Macrotherium, Dinotherium, fig. 191, Toxodon, and Mastodon. Among the forms which

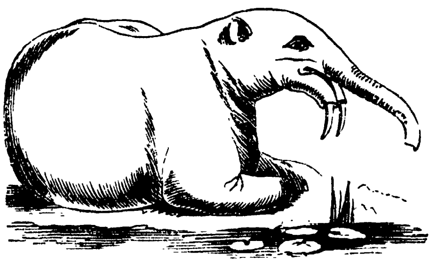


Fig. 191.—Dinotherium giganteum.

have survived, we find living types in the bear, the cat, the weasel, the seal, the mouse, the beaver, the rhinoceros, the tapir, and the stag.

507. Among the reptiles which now appeared for the first time were generic forms, whose types are snakes, frogs, and salamanders, and among the fishes, those of which the types are the perch, the herring, and the carp, fig. 192.

508. The flora of this period included Amphigamous cryptogamia (Algæ and mushrooms), Acrogenous cryptogamia (Mosses and ferns), Monocotyledons, Dicotyledonous gymnosperms (numerous conifers), Dicotyledonous angiosperms (birch, alder, oak, beech, elm, fig, plantain, poplar, laurel, rose-tree, acacia, sumach, nut-tree, sloe-tree, maple, red-jasmine, madder.)

509. The presence in all the European seas of species, both

Fig. 192.—Lebias Cephalotes. Cyprin (Carp).

animal and vegetable, now peculiar to the Torrid Zone, proves that there prevailed, in this period as in the former, in France, England, and Germany, and probably in all other parts of the globe, a uniform temperature similar to that which now characterises the tropics. Climatological lines had not therefore yet existed.

FIFTH TERTIARY PERIOD.

510. The strata deposited in this period corresponded with the older Pleiocene of Sir C. Lyell.

511. The following is a generic synopsis of the fauna, with the xception of three genera of Crustacea.

Synopsis of the Animal Kingdom (exclusive of Annulata) during the Fifth Tertiary Period.

		Genera.				
		Total.	Created.	Revived.	Extinct.	Characteristic.
Vertebrata.	Mammifers . .	72	42	30	33	25
	Birds	29	26	3	1	1
	Reptiles . . .	14	7	7	5	5
	Fishes	16	8	8	3	1
Mollusca.	Cephalopods .	1	1	0	0	0
	Gastropods . .	64	2	62	0	0
	Lamellibranchia	46	2	44	0	0
	Brachiopods .	4	0	4	0	0
	Bryozoa . . .	8	0	8	1	0
Radiata.	Echinodermata.	14	0	14	4	0
	Polyparia . .	8	0	8	3	0
	Foraminifera .	29	3	26	1	0
	Amorphozoa .	0	0	0	0	0
		305	91	214	51	32

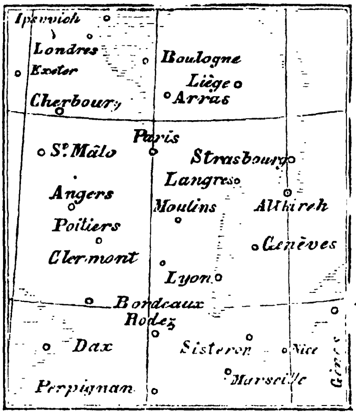
Of the Mollusca and Annulata alone 606 species have been catalogued and described. The fourth or Falunian period, as M. D'Orbigny has named it, was closed, and the fifth or sub-Apennine preceded by the geological convulsion, in which the Western Alps burst through the terrestrial crust and were elevated to their present relief.

512. The seas had again completely changed their beds in Europe, and especially in France. The three seas, which in the preceding period submerged the Ligerian, Pyrenean, and Mediterranean basins were now completely dried up, none remaining except small patches of water on the borders of the Mediterranean, in the departments, in the East Pyrenees, and in the Herault, near Montpelier. It appears, therefore, that in France land and water now assumed very nearly the forms which they possess at present, but in Piedmont the province of Asti was still submerged, as well as part of Italy, a tract round Vienna, and a great part of Eastern Europe.

513. Corresponding changes took place in the land. Switzerland, Savoy, the French departments of the Jura, the Ain, the Isère, the Higher Alps, the Lower Alps, the Drôme, Vaucluse, and the Bouches du Rhône, which had been severally to a greater or lesser extent submerged, during the Jurassic and Cretaceous ages, and during the previous periods of the Tertiary age, were now raised above the waters, and formed part of the general continent.

514. Although the western part of Europe, including France and part of Switzerland, were no longer submerged by the sea, sheets of fresh water existed in certain places. Thus, according to M. Beudant, a lake existed in France, extending north and south from Langres to Valence, fig. 193, and a similar one in Provence, between Sisteron and Verdon. The channel of Alsace, also, according to this geologist, still communicated with the ocean, and that of Piedmont, commencing from Nice and Genoa, was connected with the seas which washed the Apennines.

Fig. 193.



515. The seas of this period were peopled with the same generic forms as in the preceding, with the addition, however, of some new genera of fishes, such as the Gobius (gudgeon), Esox (pike), Cobitis (loach), Aspius (blay), and Tinca (tench).

516. The terrestrial fauna included a vast variety of forms, remarkable by their proportions and characters. Among the Mammifers were the Glyptodon, fig. 183, Megatherium, fig. 194, Megalonyx, Mylodon, fig. 195, and Mastodon, all of which are extinct. Among the genera which have since reappeared under other specific forms were elephants, fig. 196, hippopotami, camels, giraffes, horses, stags, fig. 197, p. 145, armadilloes, fig. 198, and sloths.

517. Among the birds were included genera of which the following are types, the vulture, eagle, swallow, woodpecker, chat, annabate, lark, moth-hunter, cuckoo, parrot, pheasant, common fowl, guinea-fowl, flamingo, horned-owl (hibou), rail, corncrake, goose, loon, duck, gull, grabe.

518. Among the reptiles of this period must especially be noticed the celebrated gigantic Salamander, fig. 199, found in the lacustrine limestone of Œningen. The first specimen of this fossil which was discovered obtained much notoriety from having been described as a human skeleton, under the fanciful name of *Homo diluvii testis*—a man who was witness of the deluge. Cuvier examined this specimen, and ascertained it to be the remains of a species of aquatic salamander. Other specimens of

the same fossil have been found which measured nearly five feet in length.

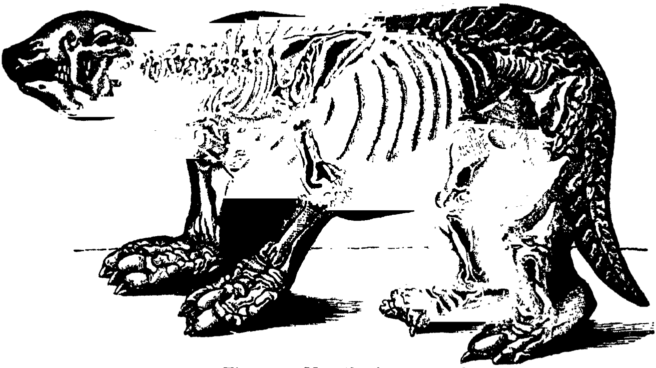


Fig. 194.—Megatherium Cuvieri.

519. To nourish the enormous herbivorous animals, which covered the land in such numbers from Italy to the Frozen

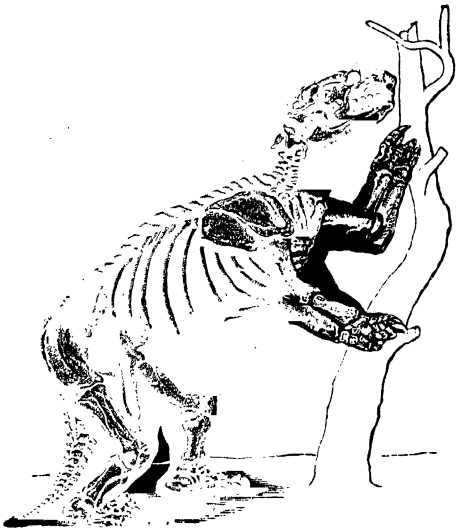


Fig. 195.—Mylodon robustus.

Ocean, and which at present are found only in those tropical

regions clothed with the richest vegetation, nature presented everywhere during this period the most varied and exuberant flora, which included nearly all the vegetable forms enumerated in

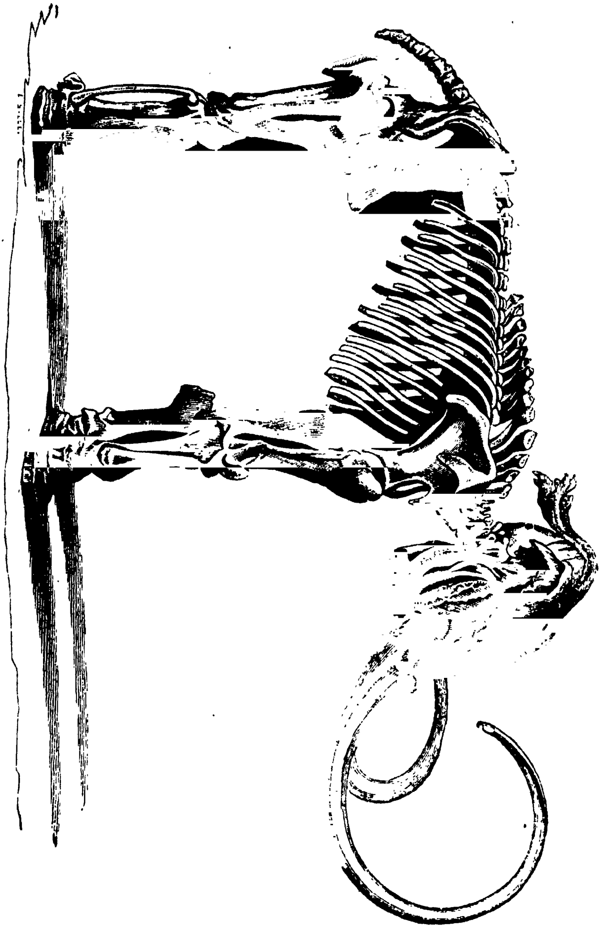


Fig. 196.—Elephas primigenius, or the Mammoth an animal of the Tertiary Age.

the preceding period, with the addition of numerous others, among which may be mentioned liquidamber, willow, myrtle, anemone, plum-tree, magnolia, holly, rhododendron, azalea, &c.

520. It is to this geological period, that the prodigious numbers of Mammifers found in the strata of the Pampas of Buenos Ayres, and in the caves which are scattered in such vast numbers over the continents of Europe and America, and even in Australia, are ascribed. In the Brazils are numerous bone-caverns, which contain genera still inhabiting the South American continent, though differing from the living species. It is worthy of especial notice, observes Dr. Mantell, that the bones of a species of horse

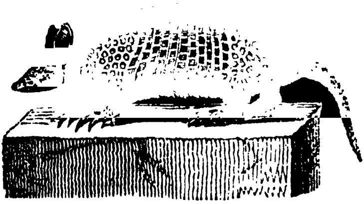


Fig. 198.—Armadillo.

occur in these accumulations, for when the Spaniards invaded the country, horses were wholly unknown to the inhabitants, who, on seeing a Spaniard on horseback, supposed that the man and horse composed a single animal. It is a marvellous event in the history of the world, that a native species should have disappeared, and should have been succeeded in after ages by countless herds of the same genus introduced by man's intervention.

521. One of the first bone-caves which attracted attention was that of Gaylenreuth in Franconia, a section of which is shown in fig. 200.

The entrance of this cave, about seven feet in height, is placed on the face of a perpendicular rock, and leads to a series of chambers from fifteen to twenty feet in height, and several hundred feet in extent, in a deep chasm. The cavern is perfectly dark, and the icicles and pillars of stalactite reflected by the torches present a highly picturesque effect. The floor is literally paved with bones and fossil teeth, and the pillars and corbels of stalactite also contain osseous remains. Cuvier showed that three-fourths of the remains in this and like caverns were those of bears, the remainder consisting of bones of hyenas, tigers, wolves, foxes, gluttons, weasels, and other Carnivora.

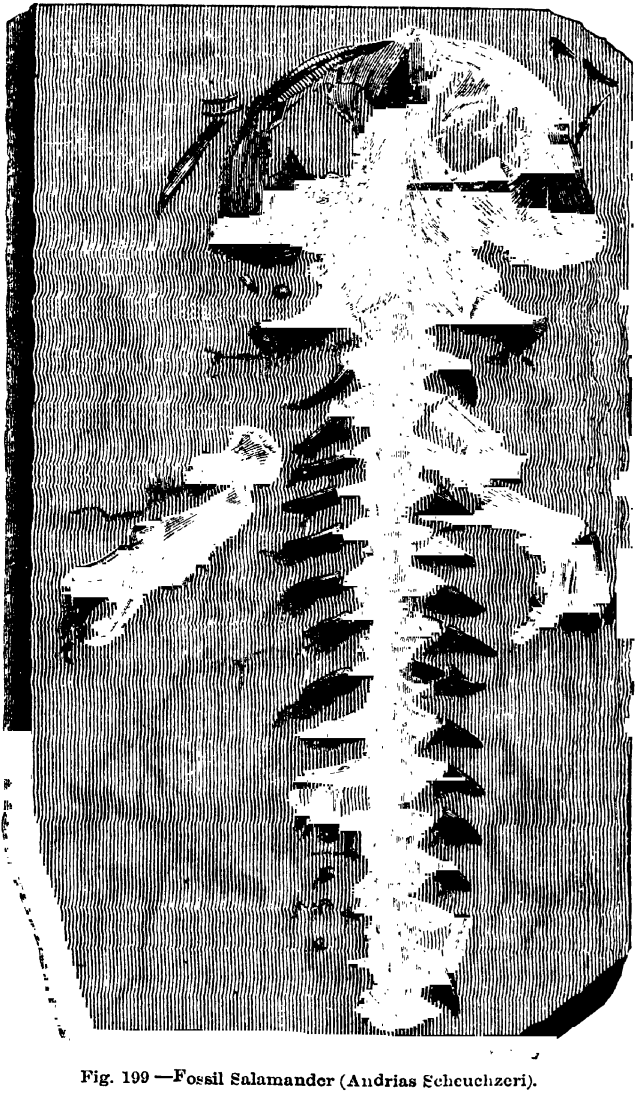


Fig. 199.—Fossil Salamander (Andrias Scheuchzeri).

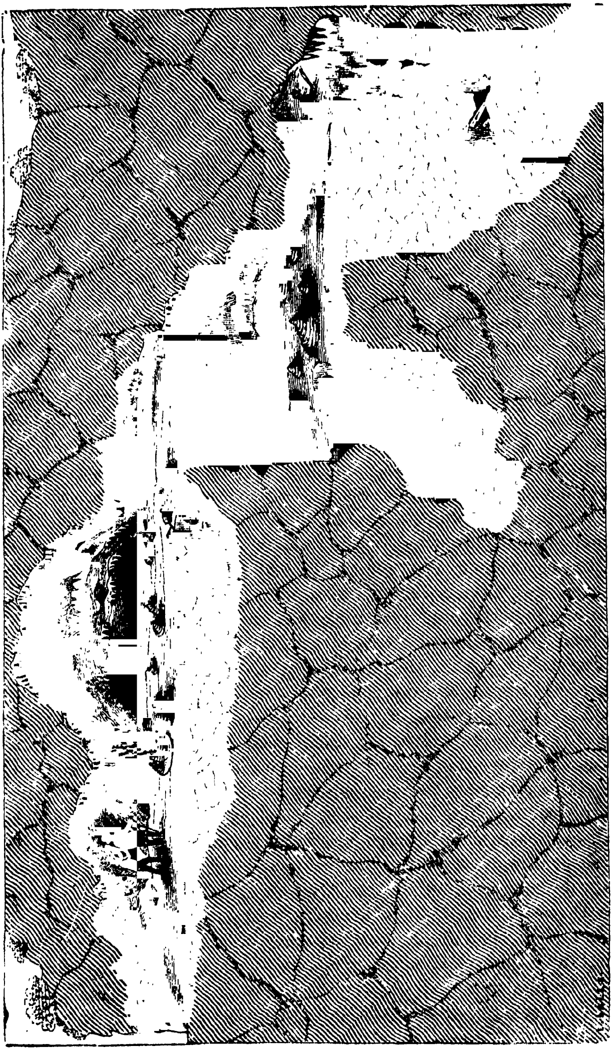


Fig. 200.—Section of the Bone Cavern of Gaylenreuth, Franconia.

RETROSPECT OF THE PRE-ADAMITE AGES.

522. Upon a review of the history of the earth previous to the appearance of the human race and its contemporary fauna and flora, as briefly sketched in the preceding pages, several considerations of high interest respecting the progressive development of organic life upon it present themselves.

Naturalists have grouped the animal world into the 20 classes indicated in the table given in (244), and have subdivided these classes into 77 orders. Each of these 77 orders is again resolved into a certain number of generic forms.

It will be matter of obvious interest to inquire in what manner the author of nature has proceeded in the work of creation, first, in considering each act of creation in itself, and independently of the others ; and secondly, in comparing one with another the successive creations described in the preceding pages.

523. Were all the forms of organic life, which existed upon the earth at any one epoch, called simultaneously into being? The habits and economy of animals answer this question. In relation to their modes of nourishment they may be resolved into two classes: the first, herbivora, consisting of those which feed on vegetables; and the second, carnivora, of those which feed either partially or exclusively on other animals.

It is clear, then, that the creation of the vegetable world must, in each case, have either preceded or have been simultaneous with that of the herbivora, since a class of animals could not be created without a provision of a food of suitable quality.

For a like reason the creation of herbivora must either have preceded or been simultaneous with that of carnivora.

524. That all parts of the earth were simultaneously peopled, not only at the first creation which took place upon it, but at all succeeding ones, is proved by the fact that the same animal and vegetable forms are found deposited in the same strata in all parts of the earth. The animal forms, for example, preserved in the Palæozoic strata of Europe are identical with those found in the corresponding formation in all parts of the world, however distant from each other, and the same is true of the Triassic, the Jurassic, and all the other groups of strata.

525. The second question, whether creative power manifested itself by a progressive development of organised forms, may be considered either with relation to orders or generic forms.

Of the seventy-seven orders of animals, an obviously increasing progression of development will be apparent on comparing age with age.

526. The number of orders of which examples are found deposited in the strata are as follows:—

Palæozoic formation	31	Cretaceous	41
Triassic	21	Tertiary	71
Jurassic	41	Existing period	77

These figures show that the orders of animals are in constantly increasing progression. The exception presented by the Triassic group may probably be explained by the want of sufficient observation of its organic remains.

527. This constant increase does not prevail with the genera. In each period each order consisted of a certain definite number of genera. Now, on comparing the number of genera of which each of these orders consisted, from period to period, it will be found that while some continually increased, others having increased up to a certain date, attained their maximum, and then decreased, and that the decrease has continued to the present time.

528. Of the seventy-seven orders, it has been found by comparison of the organic remains of the successive periods, that sixty-three have had a continually increasing number of genera from their first appearance to the present epoch, but that the numbers of the genera of the other fourteen respectively after increasing to a certain period, then decreased, and that this decrease continued.

529. Six of these fourteen orders acquired their greatest generic development in the Palæozoic period. These six consisted of two orders of Fishes, one of Crustacea, two of Mollusca, and one of Radiata.

530. The two orders of Fishes are those denominated by naturalists the *placoids* and the *ganoids*. Of the former the *shark* and the *ray*, and of the latter the *sturgeon*, are living examples.

Fig. 197.—CERVUS MEGACEROS CUVIERI.

THE PRE-ADAMITE EARTH.

CHAPTER X.

531. Examination of orders.—532. Relative numerical proportion.—533. No progression discoverable in these.—534. Examination of generic development.—535. Similar result.—536. In the Radiata and Mollusca.—537. Annulata.—538. Vertebrata.—539. No progress indicated.—540. Organs of ancient animals.—541. Examination in relation to respiratory organs.—542. Lower divisions.—543. Branchial respiration.—544. No essential change.—545. No progression observable.—546. Tracheal respiration.—547. Pulmonary respiration.—548. Composition of atmosphere unchanged.—549. General

conclusions.—550. Persistence of genera.—551. Useful geological test. **The Contemporaneous Age.**—HUMAN PERIOD. 552. Elevation of the great Alps—total destruction of the fauna and flora of the last period.—553. Great change of form in Europe.—554. Secondary effects—vast rivers and lakes producing alluvial deposits.—555. Creation of a new fauna and flora.—556. Tabular view of the existing and past animal kingdoms.—557. General inferences from this.—558. Number of species of Mollusca and Radiata, and their distribution.—559. Total number of species.—560. Creation of mankind.—561. First appearance of climatological zones.—562. Unsuccessful attempts to explain the uniform distribution of species in former ages.—563. The formation of downs—littoral deposits and the filling of lagoons and deltas supply chronological data of the present age.—564. Consistency of the Mosaic history with geological facts.—565. The future of the earth.—566. Accordance of the narrative in Genesis with geological facts.—567. Figurative use of the word day in accordance with common custom.—568. The division of the land from the water.—569. The creation of the vegetable world.—570. First creation of marine tribes and birds.—571. A similar order observed in geological phenomena.—572. Creation of Mammifers.—573. Correspondence with the Tertiary age.—574. Creation of the human race in the actual age.—575. Accordance of Scripture with geological discovery.—576. Conclusion.

531. THE order of Crustacea was that of the *Trilobites*, those of the Mollusca the Tentaculiferous Cephalopods, and the Brachiopods; and that of the Radiata the fixed Crinoids. Two had their greatest number of genera in the Jurassic period. These were the *Saurian reptiles* and the *Free Crinoids*. Four had their greatest number in the Cretaceous period, of which two were Mollusca and two Radiata. In five, two had their greatest generic development in the Tertiary period, both being Mammalia, one *Pachydermata*, and the other *Edentata*. The *elephant* is a living example of the former, and the *sloth* of the latter.

From what has been stated, it appears that of the seventy-seven orders of animals, thirty-one were called into existence during the Palæozoic period. These were distributed among the four principal divisions of animal forms, as follows:—

Vertebrata	3
Annulata	11
Mollusca	9
Radiata	8

532. Thus the four principal divisions of animal forms were represented at the first moment of creation, in a relative numerical proportion not very different from that in which they still exist. This result is completely incompatible with a notion which has been long prevalent, that creative power manifested itself by

a gradually increasing degree of organic perfection from one geological period to another, from the first appearance of animal life upon the globe to the human period.

The only facts which have given colour to this supposition, are the lateness of the period at which the Vertebrated animals of the highest order of organisation, Mammifers and Birds, appeared in any considerable numbers upon the globe, and more especially the fact, that the human race did not appear until after the close of the Tertiary age.

533. That the conclusion thus deduced is a premature generalisation, will appear from an examination of the classes and genera which have prevailed, during all the successive ages from the Palæozoic to the human.

If the supposition of progressive improvement in organisation were well founded, it must naturally be expected that in the earliest period of the Palæozoic, the lowest orders only of organisation would appear, and that consequently the Radiata alone would be found there, while on ascending through the succeeding periods of the Triassic, Jurassic, Cretaceous, and Tertiary ages we should find gradually appearing the more perfect orders of Mollusca, Annulata, and Vertebrata. On the contrary, it appears, from what has been stated, that in the Palæozoic age animals of all the orders from the lowest to the highest were created in a proportion not very different from that in which they now exist.

534. It will be interesting, however, to consider the characteristics of the organisation of the genera composing each of the orders existing at each successive period; for although no progressive increase of perfection might be manifested with regard to the *orders*, such progression might nevertheless appear in the *genera* of these orders created from period to period.

535. A due examination, however, of the genera of the several orders existing at each period will show that no such progressive increase of perfection in the organisation has been manifested.

536. Of the Radiata eight orders were called into being in the Palæozoic age, and none of superior organisation in the succeeding ages. Indeed a rigorous examination of the succession of fauna of this division leads to the contrary conclusion, showing that the most perfect prevailed in greatest numbers at the earliest ages.

A similar examination of the division of Mollusca gives a like result, no gradually increasing perfection of organisation being discoverable.

537. In like manner the supposition of progressively improved organisation from age to age would lead us to expect in Annulated animals all the orders of the less perfect organisation in the

first ages, and those of the more perfect in the later ones. As in the former cases, however, the actual results of observation are altogether opposed to this. Of the eleven orders of Annulata called into existence during the Palæozoic age there are three orders of insects—the Coleoptera, Orthoptera, and Neuroptera; one of the Arachnida, four of Crustacea, one of Cirrhipeds, and two of Annalids. Thus, as in the former case, all the classes are fairly represented. But we find further in these classes, among the three orders of Insects and four of Crustacea, the most perfectly organised of each class. We have therefore, in the case of the Annulata, the same results as were obtained in reference to the other two great divisions of the animal kingdom—the most perfectly organised being produced in the earliest ages; and not only was this the case, but they even there obtained their greatest development.

538. Although, as we have already stated, the Vertebrata present striking facts in favour of the supposition of progressive improvement already mentioned, a due examination of all the circumstances attending their gradual development, will show that no real progressive organisation has been manifested in them. If the supposition of progressively improving organisation were well founded, it must be expected that the Vertebrate animals of less complete organisation alone would appear in the Palæozoic age. We find on the contrary among the three orders of Vertebrata which appeared in that age, the Saurian reptiles and the Placoid and Ganoid fishes. Now, although mammifers and birds did not appear, the reptiles which did appear have a superior organisation to other orders which appeared later, such as serpents and Amphibia. The fishes of this epoch also are evidently superior in their organisation to many of the orders which appeared later. Although, therefore, only two of the four classes of the Vertebrata appeared during this age, of these two the most perfect specimens appeared the earliest, in contradiction to the supposition of progressively increasing perfection of organisation.

The Triassic age presented traces of the existence of the order of birds called *Waders*, and of *Chelonian reptiles* (tortoises). It is curious here to find at an epoch so remote in the history of the globe, birds the most perfect of the aerial Vertebrata, and the Chelonian reptiles, the most perfect of their class.

The Jurassic age presented no new orders of Vertebrata. The Cretaceous age presented one order of birds, the Web-footed; two of fishes, the Cycloids and Ctenoids, both less perfect than those of the Palæozoic age.

It was only, therefore, during the Tertiary age that the other

orders of Vertebrata appeared. The orders of birds which appeared at this most recent epoch were not more perfect in their organisation than the waders of the Triassic age, while the orders of reptiles, including the serpents and Amphibia, were certainly the lowest in organisation of this class.

539. It appears, therefore, that of the four classes of Vertebrata, which appeared from the earliest geological age to the present time, two, the reptiles and fishes, instead of proceeding according to the supposition of progressively improving organisation, showed a series of changes of a directly opposite character, the most perfect being the earliest, and the least perfect the most recent; while the class of birds, with reference to their organisation only, and without reference to their number, remained stationary from the Triassic to the actual period.

540. A question of high philosophical interest arises in reference to the progressive animalisation of the globe, which admits of solution by a due examination of the organic remains deposited in the strata of the earth. This question is that of determining if the various organs of the most ancient animals have remained the same from the commencement of the world, or if they have been modified in consequence of the changes which may have taken place in the external conditions of their existence.

541. Of all the organs, those of respiration are most intimately connected with this question. The several modes of animal respiration are as follows:—

1. Cutaneous respiration, made by the whole surface of the body, and not by any special organ appropriated to that function.
2. Aquatic respiration, made by means of branchia, or gills; a special organ adapted to disengage the oxygen of the air from the water and appropriate it to the vital functions.
3. Tracheal respiration, with which animals are endowed which live in the atmosphere, and appropriate its oxygen to the vital functions by means of tracheæ.
4. Pulmonary respiration, which is performed by lungs, as in the case of Mammalia generally.

Marine animals respire either without any special organ and by means of the whole surface of their bodies, or by branchia (gills).

542. The animals which respire without any special organ, are those of the lowest degree of organisation. Of these all the four classes of Echinodermata, Polyparia, Foraminifera, and Amorphozoa, appeared on the earth in the Palæozoic age in various degrees of perfection. We have therefore here, in the first epoch of creation, all the forms of cutaneous respiration.

543. The animals which have aquatic respiration by means of

branchia (gills), include nearly all the Mollusca; among the Annulata they include the Crustacea, the Annalids, and the Cirrhipeds; and among the Vertebrata, all the fishes. We find all these represented in the Palæozoic age; and, on ascending from age to age, no modification of the respiratory apparatus is manifested. The living species which have branchial respiration belong to the same class as those which exercised like functions during the Palæozoic age.

544. All these circumstances lead, therefore, to the conclusion that the external conditions in which animals exist have undergone no essential change since the Palæozoic age, inasmuch as the organs of respiration have remained the same, a conclusion which is still further confirmed when, descending from the orders, the genera are examined.

545. In fine, to the question whether the marine animals have undergone any change in their structure since the first animalisation of the globe, or if they have greatly improved in their organisation, we may answer without hesitation by an absolute negative; for these primitive genera, or those most closely allied to them, which still represent them on the earth, prove that they had from the first the organic characters which they still preserve—that they have undergone no gradual improvement in organisation—that the medium in which they lived at the earliest epoch of the creation was the same as at present—that, therefore, no great change has taken place as to the conditions of vitality of these beings, and that the seas in which they then existed are essentially similar to those which they now inhabit.

546. All the terrestrial animals, whether of land or water, which breathe otherwise then by branchia, belong to the two classes which breathe either by trachea or lungs.

Less perfect than pulmonary, tracheal respiration is peculiar to the class of insects and some Arachnida. We find this function perfectly represented in the animals of the Palæozoic epoch. As has been already stated, Coleoptera, Orthoptera, and Neuroptera, all of tracheal respiration, have been discovered in the Palæozoic strata. As these insects belong to the same or analogous genera with those which now exist, we must assume that they were endowed with the same respiratory organs. We arrive, therefore, at the conclusion, as well for terrestrial animals which breathe by trachea, as for marine animals, that the respiratory organs have not undergone any progressive improvement, and that this class in the cradle of nature was what it still is; in fine, that the medium of its terrestrial existence has always been the same, since the first animalisation of the globe to the present time.

547. Pulmonary respiration prevails in three of the principal

divisions of the animal kingdom, the Vertebrata, Annulata, and the Mollusca.

The Annulata of early geological epochs, which had pulmonary respiration, belonged to the order of Arachnida. We find, in the Carboniferous strata, one of the Palæozoic group, the remains of an Arachnid (281, fig. 143), already mentioned, closely allied to the scorpion, which it is impossible to doubt had the same organisation as scorpions of the present day, and must, therefore, have lived under like conditions of animal existence.

548. Considered in relation to their geological date, Vertebrata breathing by true lungs are found during the Palæozoic age in the form of Saurians, the most perfect of reptiles. During the Triassic age tortoises and birds appear, which of all animals have the pulmonary system the most developed. It must, therefore, be inferred, that at these remote epochs, the medium in which birds and reptiles breathing the air by lungs lived, was little if at all different from the medium in which similar classes now live, which leads to the conclusion that, at this early period in the history of the globe, the composition of the atmosphere must have been nearly the same as at present.

549. All these considerations lead to the following general conclusions:—

First. If the supposition of a gradually increasing perfection of organisation were admitted, we ought to find all the animals endowed with mere cutaneous respiration in the first stages of the world, and the others, proceeding successively from age to age, endowed with branchial, tracheal, and pulmonary respiration, whereas, on the contrary, we find in the very first epoch of the animalisation of the globe, all the modes of respiration manifested at once—a conclusion entirely at variance with the supposition of progressively improving organisation.

Secondly. Whether we compare together the increasing or decreasing development of zoological forms, or the dates of the appearance of the orders of animals with the perfection of their organs; or take for the basis of our comparative researches the physiological conclusion deduced from the mode of respiration by animals, we uniformly arrive at the same negative results relatively to the supposition of progressive improvement of animal organisation. We must, therefore, accept it as proved, that no such progressive improvement has existed.

Thirdly. No appreciable modification being found in the organs of respiration of animals from the most ancient epoch to the present, a great number of genera having always existed with the same characters since the first animalisation of the globe, it must be inferred that the vital elements have not changed, and that

the media in which animals existed, whether it be air or water, have remained the same both on land and sea.

Fourthly. The media of existence being always the same, no change in these media can be adduced as a cause for the successive extinctions and reproductions of the fauna of the earth, which have been manifested by geological phenomena as taking place during the successive geological periods, a conclusion of immense importance in the history of the globe.

Fifthly. All the researches which have been made in the fossil fauna, deposited in the strata of the earth, lead to a conclusion of high geological importance, that, until the epoch which immediately preceded the appearance of the human race and its contemporaneous tribes upon the globe, all that part of the earth which has undergone a close and accurate geological survey, including France, England, Germany, Italy, Switzerland, Spain, Portugal, part of Russia, and the adjacent seas, were inhabited by a fauna altogether tropical, and such as is at present found only under the torrid zone. We are forced, therefore, to the conclusion that, until the present period, the isothermal zones now observed had no existence.

550. Of 1473 fossil genera hitherto discovered, 16 only are found to exist in all the stages without exception. The remaining 1457 are distributed in different proportions throughout the stages. In some cases it is seen that certain genera are only found in a single stage; in others they prevail in two stages; in others in three or more; but, save in rare and exceptional cases, when they prevail in two or more stages, these stages are in regular geological succession. This persistence of the genera is a very important geological and palæontological fact. The exceptions to it do not exceed 3 per cent. of the entire number of fossil genera, and may, therefore, be regarded as arising from some accidental cause.

551. This peculiar distribution of generic forms of the fossils, supplies to the geologist most useful stratigraphical tests. Thus, if a genus known to exist only in one peculiar geological stage, be found in any part of the crust of the earth whose structure has not been previously well ascertained, its presence may be taken as a certain indication of the character and position of the stage in which it is deposited.

The Contemporaneous Age.

HUMAN PERIOD.

552. The disruption of the earth's crust, extending W. 16° S., and E. 16° N., through which the chain of the great Alps was

forced up to its present elevation (220), which, according to M. D'Orbigny, was simultaneous with that which forced up the Chilian Andes, a chain which extends over a length of 3000 miles of the Western Continent, terminated the Tertiary age, and preceded immediately the creation of the human race and its concomitant tribes. The waters of the seas and oceans, lifted from their beds by this immense perturbation, swept over the continents with irresistible force, destroying instantaneously the entire fauna and flora of the last Tertiary period, and burying its ruins in the sedimentary deposits which ensued.

553. By this dislocation, Europe underwent a complete change of form. Among the most remarkable effects were the separation of the British Isles from the mainland by the subsidence of the land between Brittany and Normandy on the one side, and Cornwall and Devon on the other, and the consequent irruption of the sea. The Mediterranean, separated from the ocean, enlarged its limits by submerging a tract south of Marseille, which had remained dry since the commencement of the Tertiary age. Europe in general took its present form and relief, with the exception of some alluvial tracts, which at a more recent period were raised above the waters, either by the disruption which produced the system of Tænarus (221) and raised Etna, Vesuvius, and Santorini, or by other local disturbances of less importance, such as partial earthquakes.

554. Secondary effects followed, which have left their traces on every part of the earth's surface. Rivers of immense magnitude poured their streams from all the elevated summits over the subjacent plains, spreading out from point to point of their course into extensive lakes, on the bottoms of which they deposited those alluvial strata of which so many examples are presented in the valleys, plains, and provinces of all the great continents. In Europe such deposits are seen in the valleys of the Rhine, the Rhone, and other great rivers, on the great plain of Crau, in the south of France, having an extent of fifty square leagues, on the plain of Bavaria, and that which spreads itself out at the foot of the Alps over the state of Lombardy and Venice.

555. When the seas had settled into their new beds, and the outlines of the land were permanently defined, the latest and greatest act of creation was accomplished by clothing the earth with the vegetation which now covers it, peopling the land and water with the animal tribes which now exist, and calling into being the human race, appointed to preside over all living things, and to manifest the glory of the Creator by the development of attributes so exalted, as to be described by the inspired author of Genesis as rendering man in a certain sense the image of his Maker.

556. To convey an approximate estimate of this fauna, we have collected and arranged, from the data supplied by M. D'Orbigny, in the following table a synopsis of the total number of generic forms of each class.

Synopsis of the generic forms included in all the fauna (exclusive of the Annulata), from the first animalisation of the earth to the human period inclusively.

	Total number, living and fossil.	LIVING. Created.	LIVING. Revived.	LIVING. Total.	FOSSIL. Extinct.	FOSSIL. Living.	FOSSIL. Total.
Mammifers	279	164	47	211	68	47	115
Birds	300	256	38	294	6	38	44
Reptiles	200	133	13	146	54	13	67
Fishes	638	360	79	439	199	79	278
Crustacea	268	168	32	200	68	32	100
Cephalopods, acetabuliferous	33	15	5	20	13	5	18
,, tentaculiferous	36	..	1	1	35	1	36
Gastropods, terrestrial and fluviatile	22	5	16	21	1	16	17
,, marine	146	25	90	115	31	90	121
Lamellibranchia, fluviatile	11	6	5	11	..	5	5
,, marine	101	9	67	76	25	67	92
Brachiopods	41	..	9	9	32	9	41
Bryozoa	87	18	21	39	48	21	69
Echinodermata, echinoids	92	21	22	43	49	22	71
,, crinoids	59	1	2	3	56	2	58
,, asteroids	20	14	3	17	3	3	6
,, ophiuroids	20	10	1	11	9	1	10
Zoophytes	309	93	38	131	178	38	216
Foraminifera	87	14	50	64	23	50	73
Amorphozoa, testaceous	36	1	..	1	35	..	35
,, corneous	15	14	1	15	..	1	1
	2800	1327	540	1867	933	540	1473

557. It appears from this, that so far as observation has supplied data for such an estimate, the total number of generic animal forms which have been called into being, since the first animalisation of the earth to the present time, has been 2800. Of this number, 1327, or nearly the half, were created at the commencement of the human period, a large proportion for one period out of thirty. It must be observed, however, that it is extremely improbable that the number of genera in past periods is as well ascertained as in the present. In the one case we have the living creation to count from; in the other we have nothing but the buried remains of the fauna of each period.

Of the number of genera, 1473, that lived in previous ages, only 540 have reappeared. There are therefore 933 generic forms unknown to the present fauna. These, as we have seen, however,

were not simultaneously extinguished, a certain number disappearing for ever at the close of each period.

558. The specific forms are far more numerous, and not so exactly ascertained. Those of fossil Mollusca and Radiata have been elaborately described and catalogued by M. D'Orbigny, who, as we have already stated, has shown that each successive period had its own assemblage of species. In the following table, compiled from the Prodrome de Paléontologie of that eminent naturalist, we have given a synopsis of the distribution of species in the successive ages and periods.

Table showing the number of species of Mollusca and Radiata by the fossil remains that have lived during the successive geological epochs and periods.

		Number of Species.	
TERTIARY AGE.	Fifth period	606	6042
	Third and fourth period	3182	
	Second period	1576	
	First ,,	678	
CRETACEOUS AGE.	Seventh period	66	4291
	Sixth ,,	1579	
	Fifth ,,	380	
	Fourth ,,	849	
	Third ,,	410	
	Second ,,	156	
	First ,,	851	
JURASSIC AGE.	Tenth period	60	3846
	Ninth ,,	199	
	Eighth ,,	655	
	Seventh ,,	739	
	Sixth ,,	281	
	Fifth ,,	546	
	Fourth ,,	603	
	Third ,,	288	
	Second ,,	301	
	First ,,	174	
TRIASSIC AGE.	Second period	792	927
	First ,,	135	
PALÆOZOIC AGE.	Fifth period	91	3180
	Fourth ,,	1047	
	Third ,,	1198	
	Second ,,	418	
	First ,,	426	
	Total	18286	18286

559. Since the date of the publication of this table, the number of ascertained species of fossil Mollusca and Radiata has been increased by further discovery, and now amounts to 21000, to which 3000 fossil species of Vertebrata and Annulata being added, gives a total number of fossil specific forms, amounting to 24000.

560. The most conspicuous condition which distinguishes the

present from all past periods, is the existence of the human race among its fauna, the attributes of which are so peculiar as to place it out of all analogy with the other classes of animals.

561. Another striking physical difference between the present and all former periods, consists in the different divisions of the earth's surface into climatological zones, each zone having its peculiar fauna and flora. In all former ages and periods, including those which immediately preceded the present, no traces of climatic distinctions have been found. It has been already shown that the fossil fauna and flora of latitudes the most different, are analogous to the fauna and flora of warm climates. Now since this uniform temperature can only be ascribed to the great predominance of the effects of the central heat of the earth over those of solar radiation, it might naturally be supposed that the change would have been gradual, and that as the surface of the earth would have cooled down by degrees, climates would have been gradually manifested, the first differing but slightly in temperature, and then from period to period the difference increasing, until at length the earth would arrive at its present condition, exhibiting the extremes and means of the torrid temperate, and frigid zones.

Observation nevertheless has not as yet supplied any facts to confirm such theoretical views. On the contrary, in the fifth Tertiary period, which immediately preceded the present epoch, it is certain that the higher latitudes had a climate similar to that which now prevails towards the Line. Plants, now limited to southern latitudes, flourished in Europe. The palms, for example, which vegetated there, have completely disappeared, having retired to warmer regions. The elephant, rhinoceros, panther, and other tropical animals which abounded in high latitudes, have also wholly disappeared there, and are limited to those latitudes where a temperature prevails conformable to their organisation. The bear still lives in Europe, but not the species which is found entombed in the strata.

562. To render the fossil fauna compatible with the existence of isothermal lines, it has been supposed that the remains of animals and plants, peculiar to warm climates, which are deposited in the strata of high latitudes, may have been transported there by ocean currents. That such an hypothesis is inadequate and inadmissible, is demonstrated by the universality of the tropical fauna of all periods. The remains, especially of land animals and vegetables, which could by any possibility have been transported by such means, must necessarily have been few and local, and would appear merely as exceptions and anomalies among the fauna and flora proper to the climatic loca-

lity. No such condition of fossil deposits, however, is observed, those of the highest latitudes being as decidedly tropical as those of the lowest.

563. The formation of downs, littoral deposits, the filling up of lagoons, and the conversion of deltas into tracts of land, are severally contemporaneous geological phenomena, which serve, by the rate of their progress, and by their cumulative effects, as a sort of natural chronometers, by which the age of the human race, and its contemporary fauna, may be approximately estimated; and it is as remarkable as it is satisfactory, that the results are in no degree of discordance with the dates of Creation supplied by chronology, based on tradition and revelation. By the general accordance of such facts, it appears that the present period has now continued for not more than six or seven thousand years.

564. After all that has been explained of the series of convulsions which terminated the succession of periods in the history of the earth, it will be evident that the Mosaic narrative of the Deluge contains nothing incompatible with that course of events, which may be said, without exaggeration, to have been of habitual occurrence on our planet. Whether the Deluge be identified with the catastrophe which produced the system of Tænarus or be ascribed to other convulsions, such as extensive earthquakes, is immaterial, so far as respects the mere credibility of the narrative. It is worthy of remark also, that the Mosaic narrative is in accordance with national tradition among various peoples.

565. As to the future, all inference must be based upon analogy with the past. During a succession of eight or nine and twenty periods, we have seen that creation after creation has taken place. Assemblage after assemblage of animated beings have peopled the earth, which has been clothed and re-clothed with vegetation for their well-being. Upon the close of period after period, it has pleased the Most High, in his inscrutable wisdom, to doom such animated worlds to sudden destruction, attaining His purpose by the secondary agency of geological convulsions. The existing animated world presents nothing which can take it out of the category of the past, or exempt it from the ultimate fate which an inexorable law has prescribed to all former creations. The earth is still subject to the same local oscillations of its crust, whether continual and gradual, or violent and sudden, as heretofore. Volcanic phenomena declare, in unequivocal language, that the heavings of the internal fluid and incandescent matter have lost none of their terrific energy. Not only, therefore, does nothing justify the supposition that the convulsion which raised the chain of the great Alps, and destroyed the fauna and flora of the fifth

Tertiary period, was the last to which the earth would be subjected, but every probability, based upon analogy to the past, points to the very opposite conclusion. When we affirm, therefore, that a moment must arrive when what we call the present world will be destroyed; when man, and all his monuments, will be involved in one common destruction, when

> "The cloud-capt towers, the gorgeous palaces,
> The solemn temples, the great globe itself,
> Yea, all that it inherits shall dissolve;
> And, like an unsubstantial pageant faded,
> Leave not a rack behind;"

we declare no more than all the analogies of the past history of the Earth confirm.

But such finality will not, as Shakspeare implies, involve the "great globe itself." The law of periodicity which characterises in a manner so remarkable all the other phenomena of nature, reappears in the acts of creation itself, and pronounces in terms not to be misunderstood the future fate of the present tenants of the earth, and shadows forth its future destination. The convulsion which will sweep away man and his works, and the tribes of animals and vegetables created for his use, and will entomb their remains, will be followed by a calm of nature, after which, if we are to trust in the permanency of the play of those creative laws which have hitherto characterised the operations of Divine power, a new assemblage of organised beings will be called into life, and a new flora will clothe the earth. Intelligences will preside over this new world with faculties as much exalted above those with which man in all his pride is endowed, as the understanding of man himself is above that of the apes, monkeys, and baboons which were at the head of the population of the last period of the Tertiary age.

566. The short account of the Creation given in the first chapter of Genesis is in accordance with the results of geological discovery, in as complete a manner as would be possible in so brief a summary, destined, not to instruct the world in geology, but, without violating truth, to convey a general notion of the work of Omnipotence in the process of creation. Light was first created, that is, the universally diffused ether, by whose properties not only light, but heat and probably electricity and magnetism, if not gravity itself, severally exist. The firmament was next made, that is, space and the stars in countless numbers which occupy it, each of which is a centre of attraction to a group of surrounding bodies, and among these stars the sun.

567. According to Genesis, the organic creation was produced in four successive intervals of time, figuratively called Days, as

we now apply that term to any period during which a certain succession of phenomena are manifested. Thus we speak of the morning and the evening of life.

> "'Tis the sunset of life gives me mystical lore,
> For coming events cast their shadows before."

568. The first epoch was preceded by the formation of the outlines of land and water. The rupture of the incipient crust of the earth, as already explained (100), by throwing the solid surface into different levels, divided the earth into oceans, seas, continents, and islands. This is stated briefly but distinctly enough in Gen. i. 9, 10: "And God said, Let the waters under the heaven be gathered together unto one place, and let the dry land appear, and it was so. And God called the dry land Earth, and the gathering of the waters called he Seas: and God saw that it was good."

569. The surface of the land was now clothed with vegetation. Verses 11, 12: "And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so. And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good."

570. The second epoch of organic creation was signalised by the production of animal life in its lowest forms, being limited to marine tribes included under the general and familiar name of Fishes. Verse 20: "And God said, Let the waters bring forth abundantly after their kind." This was succeeded by the creation of Birds: "And every winged fowl after his kind: and God saw that it was good. And God blessed them, saying, Be fruitful, and multiply, and fill the waters in the seas, and let fowl multiply in the earth."

571. In complete accordance with this account geological researches show, that in the stages which immediately rest upon the azoic formation beds of coal are found, proving that the first land was clothed with vegetation. The animal remains found in the same deposits, consist almost exclusively of marine tribes. Some foot-tracks of birds, as we have shown, are also found in these formations. No traces of land animals yet appear. Thus in accordance with Genesis, geology announces that the first acts of creation were the production of "the grass, the herb yielding seed, and the tree yielding fruit after its kind," and that then the Creator caused the "waters to bring forth abundantly after their kind," and called into existence every winged fowl after its kind.

572. The third epoch of creation was signalised by the production of Mammifers and of land animals generally (ver. 24): "And God said, Let the earth bring forth the living creature after his kind, cattle, and creeping thing, and beast of the earth after his kind: and it was so. And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind: and God saw that it was good."

573. The later geological ages, and especially the Tertiary, are here indicated, in which, as has been shown, the tribes mentioned in this short and popular statement were created.

574. The fourth, last, and latest great act of Omnipotence was the creation of the human race. On the last day or epoch of creation, "God said, Let us make man in our own image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle of the field, and over all the earth, and over every creeping thing that creepeth upon the earth. So God created man in his own image, in the image of God created he him; male and female created he them."

575. It is perhaps in this last part of the Mosaic narrative that the most striking and interesting accordance with geological science is observable. According to Genesis, the last epoch of creation was exclusively given to the creation of the human race. Naturalists have reduced animal forms to seventy-eight orders, in one of which man stands alone. It appears from the researches of palæontologists that of these seventy-eight, all but one,—that including man,—were created before the close of the Tertiary period, and that in the creation which followed that period, man was the only animal order added to those of former creations.

576. I have thought it right to develope these points at some length, inasmuch as many consciences have felt alarm at the supposed discordance between Scriptural history and geological discovery. It will, however, be seen, from what I have here stated, that not only no such discordance exists, but that making such allowances for the latitude of language, as are indispensable in the interpretation of so brief and popular a description, designed not for the scientific but for the mass of mankind, as that given in Genesis, there is the most remarkable and satisfactory accordance with natural phenomena.

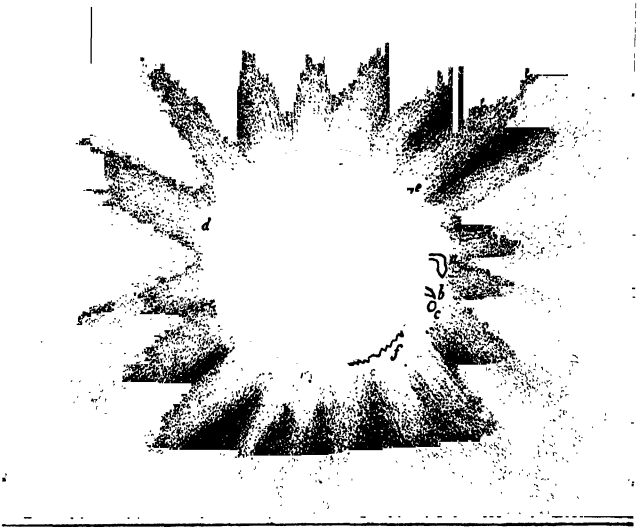


Fig. 13.

ECLIPSES.

CHAPTER I.

Mutual interposition of celestial objects.—2. Their mutual obscuration.—3. Eclipses, transits, and occultations.—4. Solar eclipse.—5. Lunar eclipse.—6. Transit of a planet.—7. Occultation of a fixed star.—8. Appearance produced by transit of an inferior planet. SOLAR ECLIPSES: 9. Effects of the relative magnitude of the discs of the sun and moon.—10. Conditions which determine eclipses.—11. Conditions under which an eclipse does not take place.—12. Condition of external contact.—13. Condition of partial eclipse—determination of its magnitude.—14. Internal contact.—15. Annular eclipse.—16. Total eclipse.—17. Greatest possible duration of a total eclipse.—18. Condition of annular eclipses.—19. Greatest possible duration of annular eclipses.—20. Solar eclipses can only occur at or near a new moon.—21. Effects of parallax.—22. Data which determine the circumstances of eclipses.—23. Solar ecliptic limits.—24. Anecdote of Columbus.—25. Baily's beads.—26. These appearances produced by lunar mountains.—27. Flame-like protuberances round the dark disc of the moon.—

28. Solar eclipse of 1851. — 29. Observations of the Astronomer Royal upon it.—30. Observations of Messrs. Dunkin and Humphreys upon it. — 31. Observations of Mr. W. Gray upon it. — 32. Observations of Messrs. Stephenson and Andrews at Fredrichsvaarn. —33. Observations of Mr. Lassell at Trollhättan Falls. — 34. Observations of Mr. Hind at Ravelsborg, near Engelholm.

1. Of the objects which in such countless numbers are scattered over the firmament, all those which constitute the solar system, except the sun itself, are in motion; and it must necessarily happen, occasionally, that some of them will assume a position between others and the eye of the observer placed upon the earth. When such an event happens the nearer of the two will intercept wholly or partially the view of the more distant. If the apparent magnitude of the nearer be greater than the more distant, such an obstruction may be total, but if less it can only be partial.

2. Since all the bodies of the solar system are illuminated by the sun, and when deprived of the sun's light are obscured and cease to be visible, it may also happen that some one of the bodies composing the system may intervene between the sun and another body, so as to deprive the latter of the light which it receives from that luminary. In such a case the object deprived of light will be rendered wholly or partially invisible, according to the relative magnitude of the two bodies, the one intercepting the light and the other being obscured.

3. Such conjunctions produce a class of occasional astronomical phenomena, which are invested with a high popular as well as a profound scientific interest. The rareness with which some of them are presented, their sudden and, to the vulgar mass, unexpected appearance, and the singular phenomena which often attend them, strike the popular mind with awe and terror. To the astronomer, geographer, and navigator, they subserve important uses, among which the determination of terrestrial longitudes, the more exact estimation of the sun's distance from the earth (which is the standard and modulus of all distances in the celestial spaces), and, in fine, the discovery of the mobility of light, and the measure of its velocity, hold foremost places.

The phenomena resulting from such contingencies of position and direction are variously denominated ECLIPSES, TRANSITS, and OCCULTATIONS, according to the relative apparent magnitudes of the interposing and obscured bodies, and according to the circumstances which attend them.

4. When the disc of the moon passes between an observer and the disc of the sun, it intercepts in this manner more or less

of the latter, and produces the phenomenon called a *solar eclipse.*

5. When the globe of the earth intervenes between the moon and the sun, it intercepts the light of the latter from a greater or lesser part of the moon's disc, and produces the phenomenon called a *lunar eclipse.*

6. When a satellite of a planet passes into such a position that the globe of the planet intervenes between the satellite and the sun, the latter is eclipsed.

7. When the disc of the moon or of a planet passes between the eye of an observer and a fixed star, the star suddenly disappears, and the phenomenon is called an *occultation* of the star.

8. When a planet passes between an observer and the sun's disc there is seen projected upon the latter a small black circular spot, and in virtue of the relative motion of the sun and planet this black spot appears to pass across the disc of the sun from east to west, producing the phenomenon called a transit of the planet. Since at the period of a transit the planet must be between the sun and the earth, and therefore nearer to the sun than the earth, this phenomenon can only happen with an inferior planet. The only planets, therefore, of which there can be transits are Venus and Mercury.

SOLAR ECLIPSES.

9. The discs of the sun and moon, though nearly equal, are not exactly so, each being subject to a variation of magnitude confined within certain narrow limits; and, in consequence, the disc of the moon is sometimes a little greater, and sometimes a little less, than that of the sun. Their centres move in two apparent circles on the firmament; that of the sun in the ecliptic, and that of the moon in a circle inclined to the ecliptic at a small angle of about 5°. These circles intersect at two opposite points of the firmament, called the moon's nodes. In consequence of the very small obliquity of the moon's orbit to the ecliptic, the distance between these paths, even at a considerable distance at either side of the node, is necessarily small. Now, since the centres of the discs of the sun and moon must each of them pass once in each revolution through each node, it will necessarily happen from time to time that they will be both at the same moment either at the node itself, or at some points of their respective paths so near it, that their apparent distance asunder will be less than the sum of their apparent semi-

diameters, and either total or partial interposition must take place, according to the relative magnitudes of their discs, and to the distance between the points of their respective paths at which their centres are simultaneously found.

10. This will be easily rendered intelligible. Let A, fig. 1, be the disc of the object eclipsed, and *a* be that of the interposing object which eclipses it. So long as the distance between the centres of the two discs is greater than the sum of their semi-diameters, it is evident that the one disc will lie altogether outside the other, so as not to intercept the view of any part of it. This will be apparent from an inspection of fig. 1.

11. This may be briefly explained thus: If R be the semi-diameter of A, and r that of a, and D be the distance between the two centres, then the one disc will lie altogether outside the other so long as D is greater than $R + r$.

Fig 1.

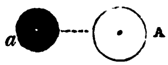
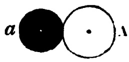


Fig. 2.



12. If the distance between the centres be equal to the sum of the two semi-diameters, then the two discs will touch each other, without either actually intercepting a part of the other. This case is shown in fig. 2, and is briefly explained thus: If $D = R + r$, the two discs will touch without encroaching one upon the other. This position of the discs is called *external contact.*

13. If the distance between the centres of the two discs be less than the sum of the two semi-diameters, then one of the discs will necessarily encroach upon the other and a partial eclipse will take place. This case is shown in fig. 3. The breadth of the

Fig. 3.

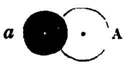
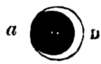


Fig. 4.



part of the disc A obscured by *a* is evidently equal to the difference between the sum of the semi-diameters of the two discs and the distance between their centres, which is briefly expressed thus: If $R + r$ be greater than D, then the one disc will encroach upon the other, and the breadth of the part intercepted will be

$$R + r - D.$$

14. If the distance between the centres of the two discs be

equal to the difference of the semi-diameters, then the one disc will lie within the other, just touching it, as shown in fig. 4. This position of the disc is called that of *internal contact*, which therefore takes place when

$$D = R - r.$$

15. If the distance between the centres be less than the sum of the semi-diameters, but greater than their difference, then a partial interposition will take place, as shown in fig. 3. If the interposing disc be less than the obscured disc, and the distance between their centres be less than the difference between the semi-diameters, then the interposing disc will lie within the obscured disc, leaving a round ring of illuminated surface, not intercepted, as shown in fig. 5. If, in this case, the centres of

Fig. 5.

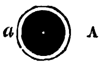
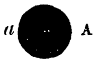


Fig. 6.



the two discs coincide, the surrounding ring of light will be of uniform breadth.

Such phenomena are called *annular eclipses*, and when the centres coincide they are said to be centrical and annular.

16. If the interposing disc be greater than the intercepted one, and at the same time the distance between the centres less than the difference of the semi-diameters, then the interposing disc will cover completely the other, and a total eclipse will take place, as shown in fig. 6. If in this case the centres of the two discs coincide, the eclipse is said to be total and central. In the case of the sun and moon the magnitude of eclipses are expressed by what are called *digits*. If the diameter of the eclipsed object, be it sun or moon, be supposed to be divided into twelve parts, each of which is called a *digit*, the eclipse is said to measure as many digits as there are such parts in the greatest breadth of the obscured part, that is, in the difference between the sum of the semi-diameter of the sun and moon and the distance between their centres. To produce a total solar eclipse, it is therefore necessary, 1st, that the apparent diameter of the moon should be equal to or greater than that of the sun; and, 2ndly, that the apparent places of their centres should approach each other within a distance not greater than the difference of their apparent semi-diameters. When these conditions are fulfilled, and so long as they continue to be fulfilled, the eclipse will be total.

17. The greatest value of the apparent semi-diameter of the moon being 1006″, and the least value of that of the sun being 945″, we shall have for the difference of their semi-diameters 61″. The greatest possible duration, therefore, of a total solar eclipse will be the time necessary for the centre of the moon to gain upon that of the sun $61'' \times 2 = 122''$. But since the mean synodic motion of the moon is at the rate of 30″ per minute, it follows that the duration of a total solar eclipse can never exceed four minutes.

18. When the apparent diameter of the moon is less than that of the sun, its disc will not cover that of the sun, even when concentrical with it. In this case, a ring of light would be apparent round the dark disc of the moon, the breadth of which would be equal to the difference of the apparent semi-diameters, as represented in fig. 5. When the discs are not absolutely concentrical, the distance between their centres being, however, less than the difference of their apparent semi-diameters, the dark disc of the moon will still be within that of the sun, and will appear surrounded by a luminous annulus, but in this case the ring will vary in breadth, the thinnest part being at the point nearest to the moon's centre; and when the distance between the centres is reduced to exact equality with the difference of the apparent semi-diameters, the ring becomes a very thin crescent, the points of the horns of which unite, as represented in fig. 4.

The greatest breadth of the crescent will be in this case equal to the difference of the apparent diameters of the sun and moon.

The greatest apparent semi-diameter of the sun being 16′ 18″, and the least apparent semi-diameter of the moon being 14′ 44″, the greatest possible breadth of the annulus when the eclipse is centrical will be

$$16' \, 18'' - 14' \, 44'' = 1' \, 34'' = 94'',$$

which is about the 20th part of the mean apparent diameter of the sun.

19. The greatest interval during which the eclipse can continue annular is the time necessary for the centre of the moon to move synodically over $94'' \times 2 = 188''$, and, since the mean synodic motion is at the rate of 30″ per minute, this interval will be about

$$\frac{188}{30} = 6{\cdot}26 \text{ minutes, or about six minutes and a quarter.}$$

20. Solar eclipses can only occur at or near a new moon. This

is evident, because the condition which limits the apparent distance between the centres of the discs to the sum of the apparent semi-diameters, involves the consequence that this distance cannot much exceed 30′, and as the difference of longitudes must be still less than this, it follows that the eclipse can only take place within less than half a degree in apparent distance, and within less than two hours of the epoch of conjunction.

21. Since the visual directions of the centres of the discs of the sun and moon vary more or less with the position of the observer upon the earth's surface, the conditions which determine the occurrence of an eclipse, and if it occur, those which determine its character and magnitude, are necessarily different in different parts of the earth. While in some places none of the conditions are fulfilled, and no eclipse occurs, in others an eclipse is witnessed which varies from one place to another in its magnitude, and in some may be total while it is partial in others.

If the change of position of the observer upon the earth's surface affected the visual directions of the centres of the two discs equally, which would be the case if they were equally distant, or nearly so, no change in the apparent distance between them would be produced, and in that case the eclipse would have the same appearance exactly to all observers in every part of the earth. But the sun being about 400 times more distant than the moon, the visual direction of the centre of its disc is affected by any difference of position of the observers, to an extent 400 times less than that of the moon's centre.

22. The relative positions of the discs of the sun and moon in the firmament, their apparent motions, and the effect produced upon their apparent positions by the varying positions of the observer upon the earth, being all known, the circumstances which determine the magnitude from minute to minute of the distance between their centres, are all given; and the problem to determine the beginning of the eclipse, or the moment at which the distance between the centres becomes equal to the sum of their apparent diameters; and the end of the eclipse, or the moment when, after diminishing and then increasing, it again becomes equal to the sum of their apparent diameters, is a matter of easy arithmetical calculation, although the practical details of such processes would not be suitable to the readers of this Tract.

23. The moon's orbit being inclined to the ecliptic at an angle of 5°, and, consequently, the distance of the moon's centre from the ecliptic varying in each month from 0° to 5°, while the interposition of the moon between any place on the earth and the sun, requires that the apparent distance of their centres should

not exceed the sum of their apparent semi-diameters, which never much exceeds half a degree, it is clear that an eclipse can never happen except when, at the time of conjunction, the apparent distance of the moon's centre from the ecliptic is within that limit, a condition which can only be fulfilled within certain small distances of the moon's nodes.

There is a certain distance from the moon's node, beyond which a solar eclipse is impossible, and a certain lesser distance, within which that phenomenon is inevitable. These distances are called the solar ecliptic limits.

24. Columbus is said to have availed himself of his acquaintance with practical astronomy to predict a solar eclipse, and used the prediction as a means of establishing his authority over the crews of his vessels, who showed indications of mutinous disobedience.

The spectacle presented during a total eclipse is always most imposing. The darkness is sometimes so intense as to render the brighter stars and planets visible. A sudden fall of temperature is sensible in the air. Vegetables and animals comport themselves as they are wont to do after sunset. Flowers close, and birds go to roost. Nevertheless, the darkness is different from the natural nocturnal darkness, and is attended with a certain indescribable unearthly light, which throws upon surrounding objects a faint hue, sometimes reddish, and sometimes cadaverously green.

Many interesting narratives have been published by scientific observers who have been so fortunate as to witness these phenomena.

25. When the disc of the moon, advancing over that of the sun, has reduced the latter to a thin crescent, it was observed by Mr. Francis Baily, that immediately before the beginning, or after the end of complete obscuration, the crescent appeared as a band of brilliant points separated by dark spaces, so as to give to it the appearance of a string of brilliant "beads." The phenomenon, which has since been frequently re-observed, thence acquired the name of "Baily's beads."

Further observation showed, that, before the formation of the "beads," the horns of the crescent were sometimes interrupted and broken by black streaks thrown across them.

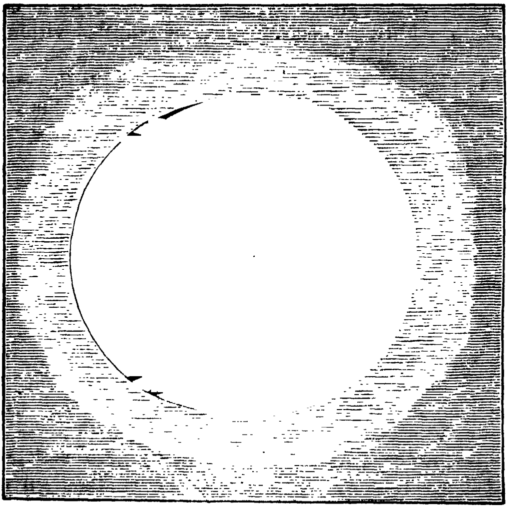
These phenomena are roughly sketched in figs. 7, 8.

Figs. 9, 10, 11, 12, are taken from the original sketches of Mr. Baily, representing the progressive disappearance of the beads after the termination of the complete obscuration.

26. These phenomena arise from the projections of the edge of the moon's disc, serrated by numerous inequalities of the surface,

approaching so close to the external edge of the sun's disc, that the points of the projections extend to the latter, while the

Fig. 7.



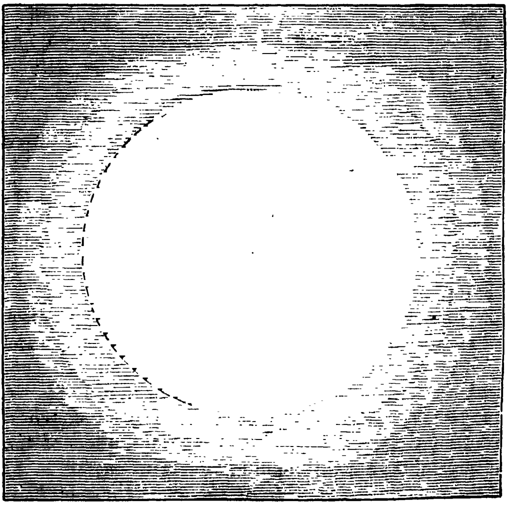


Fig. 8.

intermediate spaces remain uncovered. This may be very appropriately illustrated by laying the blade of a circular saw, having finely cut teeth, over a white circle of nearly equal diameter upon a black ground. The white parts between the teeth will appear like a necklace of white pearls.

Fig. 9.

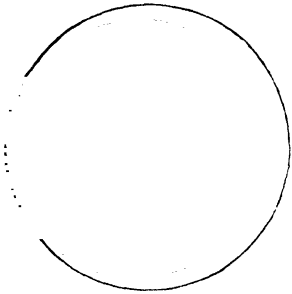
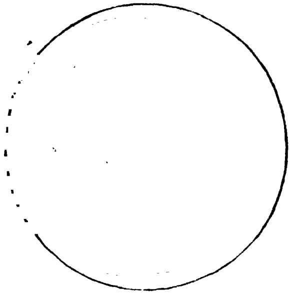


Fig. 10.



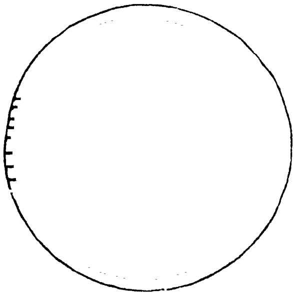


Fig. 11.

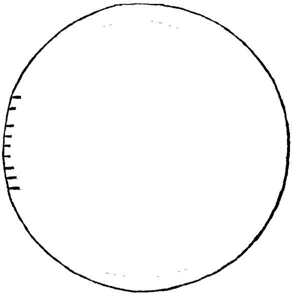


Fig. 12.

27. Immediately after the commencement of the total obscuration, red protuberances, resembling flames, appear to issue from the edge of the moon's disc. These appearances, which were first noticed by Vassenius, on the occasion of the total solar eclipse which was visible at Göttenberg on the 3rd of May, 1733, have been re-observed on the occurrence of every total solar eclipse which has taken place since that time, and constitute one of the most curious and interesting effects attending this class of phenomena.

28. A total eclipse of the sun took place on the 28th of July,

1851, which became a subject of systematic observation by the most eminent astronomers of the present day. A considerable number of English observers, aided by several foreigners, distributed themselves in parties at different points along the path of the shadow, so that the chances of the impediments that might arise from unfavourable conditions of the atmosphere might be diminished. The reports and drawings of these various observers have been collected by the Royal Astronomical Society, and published in their transactions.

The Astronomer Royal, with two assistants, Messrs. Dunkin and Humphreys, authorised by the Board of Admiralty, selected certain parts of Sweden and Denmark as the most eligible stations. Professor Airy observed at Göttenberg, Mr. Dunkin at Christiana, and Mr. Humphreys, assisted by Mr. Miland, at Christianstad.

29. The weather on the whole proved favourable at Göttenberg. We take from the report of the Astronomer Royal the following highly interesting particulars of the progress of the phenomenon.

"The approach of the totality, was accompanied with that indescribably mysterious and gloomy appearance of the whole surrounding prospect, which I have seen on a former occasion. A patch of clear blue sky in the zenith became purple-black while I was gazing at it. I took off the higher power, with which I had scrutinised the sun, and put on the lowest power (magnifying about 34 times). With this I saw the mountains of the moon perfectly well. I watched carefully the approach of the moon's limb to the sun's limb, which my graduated dark glass enabled me to see in great perfection; I saw both limbs perfectly well defined to the last, and saw the line becoming narrower and the cusps becoming sharper without any distortion or prolongation of the limbs. I saw the moon's serrated limb advance up to the sun's, and the light of the sun glimmering through the hollows between the mountain peaks, and saw these glimmering spots extinguished one after another in extremely rapid succession, but without any of the appearances which Mr. Baily has described. I saw the sun covered, and immediately slipping off the dark glass, *instantly* saw the appearances represented at *a b c d*, fig. 13 (p. 161).

"Before alluding more minutely to these, I must advert to the darkness. I have no means of ascertaining whether the darkness really was greater in the eclipse of 1842; I am inclined to think that in the wonderful, and I may say appalling, obscurity, I saw the grey granite hills within sight of Hvaläs more distinctly than the darker country surrounding the Superga. But whether because in 1851 the sky was much less clouded than in 1842 (so that the transition was from a more luminous state of sky to a

darkness nearly equal in both cases), or from whatever cause, the suddenness of the darkness in 1851 appeared to me much more striking than in 1842. My friends who were on the upper rock, to which the path was very good, had great difficulty in descending. A candle had been lighted in a lantern about a quarter of an hour before the totality; Mr. Haselgren was unable to read the minutes of the chronometer-face without having the lantern held close to the chronometer.

"The corona was far broader than that which I saw in 1842: roughly speaking, its breadth was little less than the moon's diameter; but its outline was very irregular. I did not remark any beams projecting from it which deserved notice as much more conspicuous than the others; but the whole was beamy, radiated in structure, and terminated (though very indefinitely) in a way which reminded me of the ornament frequently placed round a mariner's compass. Its colour was white, or resembling that of *Venus*. I saw no flickering or unsteadiness of light. It was not separated from the moon by any dark ring, nor had it any annular structure; it looked like a radiating luminous cloud behind the moon.

"The form of the prominences was most remarkable. That which I have marked *a* reminded me of a bomerang. Its colour for at least two-thirds of its breadth, from the convexity towards the concavity, was full lake-red, the remainder was nearly white. The most brilliant part of it was the swell farthest from the moon's limb; this was distinctly seen by my friends and myself with the naked eye. I did not measure its height; but judging generally by its proportion to the moon's diameter, it must have been 3′. This estimation perhaps belongs to a later period of the eclipse. The prominence *b* was a pale white semi-circle based on the moon's limb. That marked *c* was a red detached cloud, or balloon, of nearly circular form, separated from the moon's limb by a space (differing in no way from the rest of the corona) of nearly its own breadth. That marked *d* was a small triangular or conical red mountain, perhaps a little white in the interior. These were the appearances seen instantly after the formation of the totality.

"I employed myself in an attempt to delineate roughly the appearances on the western limb, and I took a hasty view of the country; and I then examined the moon a second time. I believe (but I did not carefully remark) that the prominences *a b c* had increased in height; but *d* had now disappeared, and a new one *e* had risen up. It was impossible to see this change without feeling the conviction that the prominences belonged to the sun and not to the moon.

"I again looked round, when I saw a scene of unexpected beauty. The southern part of the sky, as I have said, was covered with uniform white cloud; but in the northern part were detached clouds upon a ground of clear sky. This clear sky was now strongly illuminated, to the height of 30° or 35°, and through almost 90° of azimuth, with rosy-red light shining through the intervals between the clouds. I went to the telescope, with the hope that I might be able to make the polarisation-observation, (which, as my apparatus was ready to my grasp, might have been done in three or four seconds,) when I saw that the *sierra*, or rugged line of projections, shown at *f*, had arisen. This *sierra* was more brilliant than the other prominences, and its colour was nearly scarlet. The other prominences had perhaps increased in height, but no additional new ones had arisen. The appearance of this *sierra*, nearly in the place where I expected the appearance of the sun, warned me that I ought not now to attempt any other physical observation. In a short time the white sun burst forth, and the corona and every prominence vanished.

"I withdrew from the telescope and looked round. The country seemed, though rapidly, yet half unwillingly, to be recovering its usual cheerfulness. My eye, however, was caught by a duskiness in the south-east, and I immediately perceived that it was the eclipse-shadow in the air travelling away in the direction of the shadow's path. For at least six seconds this shadow remained in sight, far more conspicuous to the eye than I had anticipated."

30. Owing to the unfavourable state of the atmosphere, the observations of the other members of the Admiralty party were not so satisfactory as those of its chief. Nevertheless, both observers saw the red prominences, though imperfectly, as compared with the results of the observations of the Astronomer Royal. Baily's beads were seen by Mr. Dunkin, as well before as after the total obscuration. Their appearance was of intense brilliancy, compared by the observer to a diamond necklace. Their effect on the observer was "quite overpowering," being unprepared for a sight so magnificent.

At Christianstad, the planets Venus, Mercury, and Jupiter, and the stars Arcturus and Vega, were visible during the totality of the eclipse.

31. Mr. W. Gray, stationed at Tune, near Sarpsborg, saw the beads, both before and after the total obscuration. He saw four of the red projections, three of which are represented in fig. 14, the fourth resembling *c* and *d* in form, and diametrically opposite to *a* in position on the moon's limb.

During the totality, the light seemed like that of an evening in August at an hour and a half after sunset.

32. Messrs. Stephenson and Andrews, at Fredrichsvaarn, saw Baily's beads both before and after the total obscuration. The

Fig. 14.

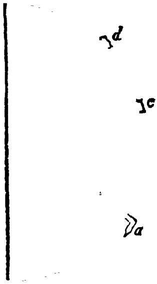
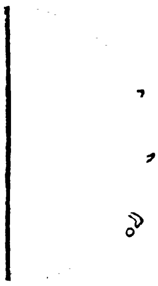


Fig. 15.

crescent, before disappearing, was seen as a fine thread of light, which broke up into fragments, and when it re-appeared, it gave the idea of globules of mercury rushing amongst each other along the edge of the moon. In a second or two after the disappearance of the crescent, a rose-coloured flame shot out from the limb of the moon, which in form resembled a sickle (see fig. 15). It increased rapidly, and then two other rose-coloured prominences, above and below it, started out, differing in shape, but evidently of the same character. Besides these, there were, as well between them as elsewhere, around the moon's edge other lurid points and other indistinct lines. The height of the principal prominence was estimated at about the twentieth of the moon's diameter, that is, about $1\frac{1}{2}'$. The chief prominences looked like burning volcanoes, and the lurid points and lines reminded the observers of dull streams of cooling lava.

Fig. 16.



33. Mr. Lassell, at Trollhättan Falls, having heard the red prominences seen in former total eclipses described as faint appearances, saw with astonishment around the dark disc of the moon, after the commencement of total obscuration, prominences of the most brilliant lake colour,—a splendid pink, quite defined and hard, fig. 16. They appeared not to be absolutely quiescent. The observer judged from their appearance that they belonged to the sun, and not to the moon.

34. Mr. Hind, at Ravelsborg, near Engelholm, saw the beads, both before and after the total obscuration, in such a manner as to leave no doubt of their cause being that already explained. In five seconds after the commencement of the total obscuration, the corona or glory around the moon's disc was seen. Its colour seemed to be that of tarnished silver, brightest next the moon's limb, and gradually fading to a distance equal to one-third of her diameter, where it became confounded with the general tint of the heavens. Appearances of radiation are mentioned, similar to those described by Professor Airy.

"On first viewing the sun," says Mr. Hind, "without the dark glass after the commencement of totality, the rose-coloured prominences immediately caught my eye, and others were seen a few seconds later (fig. 17, p. 177). The largest and most remarkable of them was situate about 5° north of the parallel of declination, on the western limit of the moon; it was straight through two-thirds of its length, but curved like a sabre near the extremity, the concave edge being towards the horizon. The edges were of a full rose-pink, the central parts plainer, though still pink.

"Twenty seconds, or thereabouts, after the disappearance of the sun, I estimated its length at 45″ of arc, and on attentively watching it towards the end of totality, I saw it materially lengthened (probably to 2′), the moon having apparently left more and more of it visible as she travelled across the sun. It was always curved, and I did not remark any change of form, nor the slightest motion during the time the sun was hidden. I saw this extraordinary prominence *four seconds after the end of totality*, but at this time it appeared detached from the sun's limb, the strong white light of the corona intervening between the limb and the base of the prominence.

"About 10° south of the above object I saw, during the totality, a detached triangular spot of the same rose colour, suspended, as it were, in the light of the corona, which gradually receded from the moon's dark limb, as she moved onwards, and was, therefore, clearly connected with the sun. Its form and position, with respect to the large prominence, continued exactly the same so long as I observed it. On the south limb of the moon appeared a long range of rose-coloured flames, which seemed to be affected with a tremulous motion, though not to any great extent.

"The bright rose-red of the tops of these projections gradually faded towards their bases, and along the moon's limb appeared a bright narrow line of a deep violet tint: not far from the western extremity of this long range of red flames was an isolated prominence, about 40″ in altitude, and another of similar size and form, at an angle of 145° from the north towards the east: the

moon was decidedly reddish purple at the beginning of totality, but the reddish tinge disappeared before its termination, and the disc assumed a dull purple colour. A bright glow, like that of twilight, indicated the position where the sun was about to emerge, and three or four seconds later the beads again formed, this time instantaneously, but less numerous, and even more irregular, than before. In five seconds more the sun reappeared as a very fine crescent on the sudden extinction of the beads."

Fig. 17.

Fig. 18.

ECLIPSES.

CHAPTER II.

35. Observations of Mr. Dawes near Engelholm.—36. Effects of total obscuration on surrounding objects and scenery.—37. Evidence of a solar atmosphere.—38. Probable causes of the red emanations in solar eclipses. LUNAR ECLIPSES: 39. The earth's conical shadow.—40. Its section may be regarded as a dark disc moving on the firmament.—41. Conditions which determine lunar eclipses.—42. Lunar ecliptic limits.—43. Greatest duration of total lunar eclipses.—44. Effects of the earth's penumbra.—45. Effects of refraction of the earth's atmosphere in total lunar eclipse.—46. Lunar disc visible during total obscuration.

35. MR. DAWES near Engelholm observed the beads, and found all the circumstances attending their appearance, such as to leave no doubt as to the truth of the cause generally assigned to them. He observed the corona, a few seconds after the commencement of the totality, and estimated its extreme breadth at half the moon's diameter, the brightness being greatest near the moon's limb, and gradually decreasing outwards. The phenomena of the red protuberances, witnessed by Mr. Dawes, are so clearly and satisfactorily described by him, that we think it best here to give the account of them in his own words:—

"Throughout the whole of the quadrant, from north to east, there was no visible protuberance, the corona being uniform and uninterrupted. Between the east and south points, and at an angle of about 170° from the north point, appeared a large red prominence of a very regular conical form, fig. 18. When first seen, it might be about $1\frac{1}{2}'$ in altitude from the edge of the moon, but its length diminished as the moon advanced.

"The position of this protuberance may be inaccurate to a few degrees, being more hastily noticed than the others. It was of a deep rose colour, and rather paler near the middle than at the edges.

"Proceeding southward, at about 145° from the north point commenced a low ridge of red prominences, resembling in outline the tops of a very irregular range of hills. The highest of these probably did not exceed 40″. This ridge extended through 50° or 55°, and reached, therefore, to about 197° from the north point, its base being throughout formed by the sharply-defined edge of the moon. The irregularities at the top of the ridge seemed to be permanent, but they certainly appeared to undulate from the west towards the east; probably an atmospheric phenomenon, as the wind was in the west.

"At about 220° commenced another low ridge of the same character, and extending to about 250°, less elevated than the other, and also less irregular in outline, except that at about 225° a very remarkable protuberance rose from it to an altitude of 1½′, or more. The tint of the low ridge was a rather pale pink; the colour of the more elevated prominence was decidedly deeper, and its brightness much more vivid. In form it resembled a *dog's tusk*, the convex side being northwards, and the concave to the south. The apex was somewhat acute. This protuberance, and the low ridge connected with it, were observed and estimated in height towards the end of the totality.

"A small double-pointed prominence was noticed at about 255°, and another low one with a broad base, at about 263°. These were also of the rose-coloured tint, but rather paler than the large one at 225°.

"Almost directly preceding, or at 270°, appeared a bluntly triangular pink body, *suspended*, as it were, in the corona. This was separated from the moon's edge when first seen, and the separation increased as the moon advanced. It had the appearance of a large conical protuberance, whose base was hidden by some intervening soft and ill-defined substance, like the upper part of a conical mountain, the lower portion of which was obscured by clouds or thick mist. I think the apex of this object must have been at least 1′ in altitude from the moon's limb when first seen, and more than 1½′ towards the end of total obscuration. Its colour was pink, and I thought it paler in the middle.

"To the north of this, at about 280° or 285°, appeared the most wonderful phenomenon of the whole. A red protuberance, of vivid brightness and very deep tint, arose to a height of, perhaps, 1½′ when first seen, and increased in length to 2′, or more, as the moon's progress revealed it more completely. In shape it some-

what resembled a *Turkish cimeter*, the northern edge being convex, and the southern concave. Towards the apex it bent suddenly to the south, or upwards, as seen in the telescope. Its northern edge was well defined, and of a deeper colour than the rest, especially towards its base. I should call it a *rich carmine*. The southern edge was less distinctly defined, and decidedly paler. It gave me the impression of a somewhat conical protuberance, partly hidden on its southern side by some intervening substance of a soft or flocculent character. The apex of this protuberance was paler than the base, and of a purplish tinge, and it certainly had a flickering motion. Its base was, from first to last, sharply bounded by the edge of the moon. To my great astonishment, this marvellous object *continued visible for about five seconds*, as nearly as I could judge, *after the sun began to reappear*, which took place many degrees to the south of the situation it occupied on the moon's circumference. It then rapidly faded away, *but it did not vanish instantaneously*. From its extraordinary size, curious form, deep colour, and vivid brightness, this protuberance absorbed much of my attention; and I am, therefore, unable to state precisely what changes occurred in the other phenomena towards the end of the total obscuration.

"The arc, from about 283° to the north point, was entirely free from prominences, and also from any roseate tint."

36. Although the different parties of observers scattered over the path of the moon's shadow were not equally fortunate in having a clear unclouded sky, they were all enabled to observe and record the effects of the total obscuration upon the surrounding objects and country. Dr. Robertson of Edinburgh, Dr. Robinson of Armagh, and some others, witnessed the eclipse from an island off the coast of Norway, in lat. 61° 21′, at a point in the path of the axis of the shadow. The precursory phenomena corresponded with those described by other observers. The atmosphere was, however, obscured by clouds, which appeared to rush down in streams from the place of the sun. The sea-fowl flocked to their customary places of rest and shelter in the rocks. The darkness at the moment of total obscuration was sudden, but not absolute; for the clouds had left an open strip of the sky, which assumed a dark lurid orange, which changed to greenish colour in another direction, and shed upon persons and objects a faint and unearthly light. Lamps and candles, seen at fifty or sixty yards' distance, were as visible as in a dark night, and the redness of their light presented a strange contrast with the general green hue of everything around them. "The appearance of the country," says Dr. Robertson, "seen through the lurid opening under the clouds, was most appalling. The distant peaks of the Tostedals and

Dorieffeld mountains were seen still illuminated by the sun, while we were in utter darkness. Never before have we observed all the lights of heaven and earth so entirely confined to one narrow stripe along the horizon,—never that peculiar greenish hue, and never that appearance of outer darkness in the place of observation, and of excessive distance in the verge of the horizon, caused in this case by the hills there being more highly illuminated as they receded, by a less and less eclipsed sun."

Mr. Hind says, that during the obscuration "the entire landscape was overspread with an unnatural gloom; persons around him assumed an unearthly cadaverous aspect; the distant sea appeared of a lurid red; the southern heavens had a sombre purple hue, the place of the sun being indicated only by the CORONA; the northern heavens had an intense violet hue, and appeared very near. On the east and west of the northern meridian, bands of light of a yellowish crimson colour were seen, which gradually faded away into the unnatural purple of the sky at greater altitudes, producing an effect that can never be effaced from the memory, though no description could give a just idea of its awful grandeur."

At several places in Prussia, where the heavens were unclouded during the total obscuration, a great number of the more conspicuous stars, as well as the planets Jupiter, Venus, and Mercury, were visible. Several flowering plants were observed to close their blossoms, birds which had been previously flying about disappeared, and domestic fowls went to roost.

37. Many of the phenomena attending total solar eclipses afford strong corroboratory evidence of the existence of a solar atmosphere, extending to a vast height above the luminous coating of the sun.

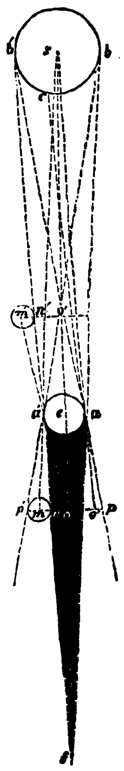
The corona, or bright ray or glory, surrounding the dark disc of the moon where it covers the sun, is observed to be concentric with the moon only at the moment when the latter is concentric with the sun. In other positions of the moon's disc, it appears to be concentric with the sun. This would be the effect produced by a solar non-luminous atmosphere faintly reflecting the sun's light.

38. It appears to be agreed generally among astronomers that the red emanations above described are solar, and not lunar. If they be admitted then to be solar, it is scarcely possible to imagine them to be solid matter, notwithstanding the apparent constancy of their form in the brief interval during which at any one time they are visible, for the entire duration of their visibility has never yet been so much as four minutes. To admit the possibility of their being solar mountains projecting above the luminous atmosphere surrounding the sun, and rising to the height

in the exterior and non-luminous atmosphere forming the corona necessary to explain their appearance, we must suppose their height to amount to nearly a twentieth part of the sun's diameter, that is to 44000 miles.

The fact that they are gaseous and not solid matter appears, therefore, to be conclusively established by their enormous magnitude, the great height above the surface of the sun at which they are placed, their faint degree of illumination, and the circumstances of their being sometimes detached at their base from the visible limb of the sun. These circumstances render it probable that these remarkable appearances are produced by cloudy masses of extreme tenuity, supported, and probably produced in an extensive spherical shell of non-luminous gaseous matter, surrounding and rising above the luminous surface of the sun to a great altitude.

Fig. 19.



LUNAR ECLIPSES.

39. As the earth moves in its orbit round the sun it projects behind it a conical shadow, the axis of which is always directed to that point of the heavens which is in immediate opposition to the centre of the sun. A section of the sun *s*, and the earth *e*, and of the conical shadow made by a plane passing through the centres of the sun and earth, is shown in fig. 19.

It will be evident whenever the globe of the moon or any part of it enters within the limits of the conical shadow *a f a'*, it will be deprived of the sun's light, and will consequently be eclipsed; the circumstances, therefore, which determine lunar eclipses will depend upon the transverse section of the shadow at the moon's distance from the earth, this distance being about one-third of the total length of the conical shadow.

It is found by calculation that its greatest apparent diameter, as seen from the earth, is 45′ 42″, and its least 37′ 49″. Its mean magnitude is, therefore, 41′ 45″.

40. The section of the shadow may, therefore, be regarded as a dark disc, whose apparent semi-diameter varies between 37′ 49″ and 45′ 42″, and the true place of whose centre is a point on the ecliptic 180° behind the centre of the sun. A lunar eclipse is

produced by the superposition, partial or total, of this disc on that of the moon, and the circumstances and conditions which determine such an eclipse are investigated upon the principles already explained.

41. By the solar tables, the apparent position of the centre of the sun, from hour to hour, may be ascertained, and the position of the centre of the section of the shadow may thence be inferred. From the lunar tables, the position of the moon's centre being in like manner determined, the distance between the centres of the section of the shadow and the moon's disc can be ascertained.

The magnitude of the eclipse is measured by the difference between the sum of the semi-diameters and the distance between the centres.

42. That a lunar eclipse may take place, it is necessary that the moon, when in opposition, should approach the ecliptic within a distance less than the sum of the apparent semi-diameters of the moon and the section of the shadow.

When the distance from the node at opposition is greater than 5° 44′ 21″, a total eclipse cannot, and when less than 3° 54′ 5″, it must, take place. Between these limits it may or may not occur, according to the magnitude of the parallaxes and apparent diameters.

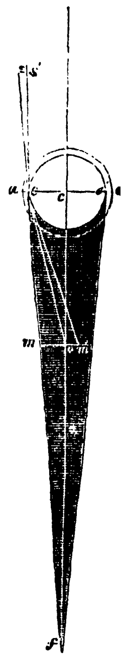
43. The duration of a total eclipse depends on the distance over which the centre of the moon's disc moves relatively to the shadow, while passing from the first to the last internal contact. This may vary from 0, to twice the greatest possible distance of the moon's centre from the centre of the shadow, at the moment of internal contact.

44. Long before the moon enters within the sides of the cone of the shadow it enters the penumbra, and is partially deprived of the sun's light, so as to render the illumination of its surface sensibly more faint. When once it passes within the line *a′ p′*, fig. 19, forming the external limit of the penumbra, it ceases to receive light from that part of the sun which is near the limb *b*. As it advances closer to *a′ f*, the edge of the true shadow, more and more of the solar rays are intercepted by the earth; and when it approaches the edge, it is only illuminated by a thin crescent of the sun, visible from the moon over the edge of the earth at *a′*. It might be thus inferred, that the obscuration of the moon is so extremely gradual, that it would be impossible to perceive the limitation of the shadow and penumbra. Nevertheless, such is the splendour of the solar light, that the thinnest crescent of the sun, to which the part of the moon's surface near the edge of the earth's shadow is exposed, produces a degree of illumination which contrasts so strongly with the shadow as to

render the boundary of the latter so distinct, that the phenomenon presents one of the most striking evidences of the rotundity of the earth, the form of the shadow being accurately that which one globe would project upon another.

45. If the earth were not surrounded with an atmosphere capable of refracting the sun's light, the disc of the moon would be absolutely invisible after entering within the edge of the shadow. For the same reason, however, that we continue to see the sun's disc, and receive its rays after it has really descended below the horizon, an observer placed upon the moon, and therefore the surface of the moon itself, must continue to receive the sun's rays after the interposition of the edge of the earth's disc as seen from the moon. This refracted light falling upon the moon after it has entered within the limits of the shadow, produces upon it a peculiar illumination, corresponding in faintness and colour to the rays thus transmitted through the earth's atmosphere.

Fig. 20.



To render this more clear, let *e e'*, fig. 20, represent a diameter of the earth at right angles to the axis *c f* of the shadow, and let *a a'* represent the limits of the atmosphere. Let *s c f* be the ray proceeding from the edge of the sun, and forming therefore the boundary of the shadow, considered without reference to the atmosphere. But the solar rays in passing through the convex shell of air, between *a* and *e*, are affected as they would be by a convex lens composed of a transparent refracting medium, and are therefore rendered convergent, so that the ray *s e*, instead of passing directly to *m*, will be bent inwards towards *m'*, while the ray which really passes from *e* to *f* is one which comes in the direction *s' e*, and therefore from a point within the sun's disc. The moon's disc, therefore, or any point of it which is within the angle *m e m'*, will receive this refracted light, and will be illuminated by it in accordance with its colour and intensity.

The deflection which a solar ray suffers in passing through the atmosphere towards *e* on the side of the sun, is equal to the horizontal refraction; and as, according to the principles of optics, it suffers an equal refraction in passing out on the other side, the total deflection, which is measured by the angle *m e m'*, is twice

the horizontal refraction. But the mean value of the horizontal refraction being 33′, the mean value of the angle *m e m′* will be 66′. But since the greatest value of *m e o* is 45′ 42″, it follows that the refracted ray *e m′* will fall upon the section of the shadow at a point beyond its centre; and since the same will take place at all points round the shadow, it follows that the entire section will be more or less illuminated by the light thus refracted: the intensity of such illumination increases from the centre towards the borders.

46. When the moon's limb first enters the shadow at *m*, the contrast and glare of the part of the disc still enlightened by the direct rays of the sun render the eye insensible to the more feeble illumination produced upon the eclipsed part of the disc by the refracted rays. As, however, the eclipse proceeds, and the magnitude of the part of the disc directly enlightened decreases, the eye, partly relieved from the excessive glare, begins to perceive very faintly the eclipsed limb, which is nevertheless visible from the beginning in a telescope, in which it appears with a dark grey hue. When the entire disc has passed into the shadow, it becomes distinctly visible, showing a gradation of tints from a bluish or greenish on the outside to a gradually increasing red, which, further in, changes to a colour resembling that of incandescent iron when at a dull red heat. As the lunar disc approaches the centre of the shadow, this red line is spread all over it. Its illumination in this position is sometimes so strong as to throw a sensible shadow, and to render distinctly visible in the telescope the lineaments of light and shadow upon its surface.

These effects are altogether similar to the succession of tints developed in our atmosphere at sunset, and arise, in fact, from the same cause, operating, however, with a two-fold intensity. The solar rays traversing twice the thickness of air, the blue and green lights are more effectually absorbed, and a still more intense red is imparted to the tints transmitted. Without pursuing these consequences further here, the student will find no difficulty in tracing them in the effects of sunset and of sunrise, and of evening and morning twilight.

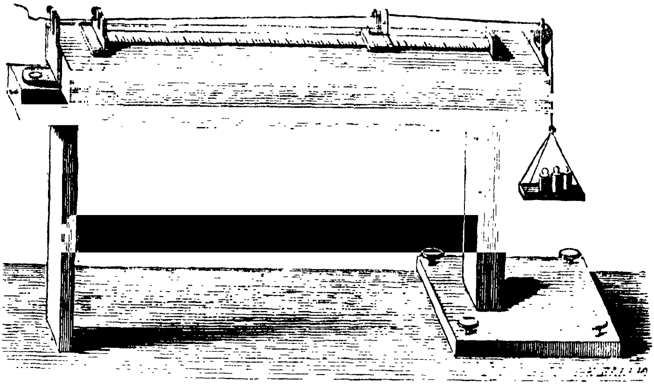


Fig. 2.—A MONOCHORD, OR SONOMETER.

SOUND.

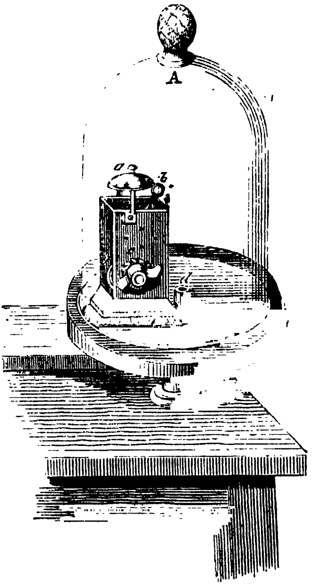
1. SOUND is the sensation produced in the organs of hearing when they are affected by undulations transmitted to them through the atmosphere. These undulations are subject to an infinite variety of physical conditions, and each variety is followed by a different sensation.

2. That the presence of air or other conducting medium is indispensable for the production of sound, is proved by the following experiment.

Let a small apparatus (fig. 1, p. 186) called an alarum, consisting of a bell *a*, which is struck by a hammer *b*, moved by clockwork, be placed under the receiver of an air-pump, through the top of which a rod slides, air-tight, the end of the rod being connected with a detent which governs the motion of the clockwork connected with the hammer. This rod can, by a handle placed outside the receiver, be made to disengage the detent, so as to make the bell ring whenever it is desired.

This arrangement being made, and the alarum being placed within the receiver, upon a soft cushion of wool *e*, so as to prevent the vibration from being communicated to the pump-plate, let the receiver be exhausted in the usual way. When the air has been withdrawn, let the bell be made to ring by means of the sliding-rod. No sound will be heard, although the percussion of the tongue upon the bell, and the vibration of the bell itself, are visible. Now if a little air be admitted into the receiver, a faint sound will begin to be heard, and this sound will become gradually louder in proportion as the air is gradually readmitted.

Fig. 1.



In this case the vibrations which directly act upon the ear are not those of the air contained in the receiver. These latter act upon the receiver itself and the pump-plate, producing in them sympathetic vibration; and those vibrations impart vibrations to the external air which are transmitted to the ear.

If in the preceding experiment a cushion had not been interposed between the alarum and the pump-plate, the sound of the bell would have been audible, notwithstanding the absence of air from the receiver. The vibration in this case would have been propagated, first from the bell to the pump-plate and to the bodies in contact with it, and thence to the external air.

3. Since the propagation of undulations through the atmosphere is progressive, an interval of time, more or less, must elapse between the vibration of the sounding body and the perception of the sound by a hearer, and such interval will be proportionate to the distance of the hearer from the sounding body, and to the velocity with which sound is propagated through the intervening medium. This progressive propagation of sound can be directly proved by experiment.

Let a series of observers, A, B, C, D, &c., be placed in a line, at distances of about 1000 feet asunder, and let a pistol be discharged at P, about 1000 feet from the first observer.

This observer will see the flash of the pistol about one second before he hears the report. The observer B will hear the report one second after it has been heard by A, and about two seconds after he sees the flash. In the same manner, the third observer at C will hear the report one second after it has been heard by the observer at B, and two seconds after it has been heard by the observer at A, and three seconds after he perceives the flash. In the same way, the fourth observer at D will hear the report one second later than it was heard by the third observer at C, and three seconds later than it was heard by the observer at A, and four seconds after he perceives the flash.

Now it must be observed, that at the moment the report is heard by the second observer at B, it has ceased to be audible to the first observer at A; and when it is heard by the third observer at C, it has ceased to be heard by the second observer at B, and so forth. It follows, therefore, from this, that sound passes through the air, not instantaneously, but progressively, and at a uniform rate.

4. As the sensation of sound is produced by the wave of air impinging on the tympanum of the ear, exactly as the momentum of a wave of the sea would strike the shore, it follows that the interval between the production of sound and its sensation, is the time which such a wave would take to pass through the air from the sounding body to the ear; and since these waves are propagated through the air in regular succession, one following another without overlaying each other, the breadth of a wave may always be determined if we take the number of vibrations which the sounding body makes in a second, and the velocity with which the sound passes through the air. If, for example, it be known that in a second a musical string makes 500 vibrations, and that the sound of this string takes a second to reach the ear of a person at a distance of 1000 feet, there are 500 waves in the distance of 1000 feet, and consequently each wave measures two feet.

The velocity of the sound, therefore, and the rate of vibration, are always sufficient data by which the length of a sonorous wave can be computed.

5. It has not been ascertained, with any clearness or certainty, by what physical distinctions vibrations which produce common sounds or noises are distinguished from such as produce musical

sounds. It is nevertheless certain, that all vibrations, in proportion as they are regular, uniform, and equal, produce sounds proportionably more agreeable and musical.

Sounds are distinguished from each other by their *pitch* or *tone*, in virtue of which they are high or low; by their *intensity*, in virtue of which they are loud or soft; and by a property expressed in French by the word *timbre*, which we shall here adopt in the absence of any English equivalent.

6. The pitch or tone of a sound is grave or acute. In the former case it is low, and in the latter high, in the musical scale.

The more rapid the vibrations are, the more acute will be the sound. A bass note is produced by vibrations much less rapid than a note in the treble.

All vibrations which are performed at the same rate produce waves of equal length and sounds of the same pitch.

7. The intensity of a sound, or its degree of loudness, depends on the force with which the vibrations of the sounding body are made.

8. The timbre of a sound is not easily explained, and still less easily can the physical conditions on which it depends be ascertained. If we hear the same musical note produced with the same degree of loudness in an adjacent room successively upon a flute, a clarionet, and a hautboy, we shall, without the least hesitation, distinguish the one instrument from the other. Now this distinction is made by observing some peculiarity in the notes produced, yet the notes shall be the same, and be produced with equal loudness.

9. It is manifest from the absence of all confusion in the effects of music, at whatever distance it may be heard, that in the same medium all sounds have the same velocity. If the different notes simultaneously produced by the various instruments of an orchestra moved with different velocities through the air, they would be heard by a distant auditor at different moments, the consequence of which would be, that a musical performance would, to the auditors, save those in immediate proximity with the performers, produce the most intolerable confusion and cacophony; for different notes produced simultaneously, and which, when heard together, form harmony, would at a distance be heard in succession; and sounds produced in succession would be heard as if produced together, according to the different velocities with which each note would pass through the air.

10. The velocity of sound varies with the elasticity of the medium by which it is propagated. Its velocity, therefore, through the air will vary, more or less, with the barometer and thermometer.

The experimental methods which have been adopted to ascertain the velocity of sound are similar in principle to those which have

been briefly noticed by way of illustration. The most extensive and accurate system of experiments which have been made with this object, were those made at Paris by the Board of Longitude in the year 1822. The sounding bodies used on this occasion, were pieces of artillery charged with from two to three pounds of powder, which were placed at Villejuif and Montlhéry. The experiments were made at midnight, in order that the flash might be more easily and accurately noticed. They were conducted by MM. Prony, Arago, Mathieu, Humboldt, Gay Lussac, and Bouvard. The result of these experiments was, that when the barometer was at 29·8 inches, and the thermometer at 61°, the velocity of sound was 1118·4 feet per second.

According to the theory of Laplace, the velocity of sound increases at the rate of 1·11 feet per second for every degree in the rise, and decreases at the same rate for each degree in the fall of the thermometer. Hence it appears that the velocity of sound at 32° is 1086·2 feet per second. For all practical purposes, it is sufficiently exact to take 1120 feet as the velocity of sound at 62°, and allow thirteen inches for every variation of a degree in temperature.

11. The production of sound is in many cases attended with the evolution of light, as, for example, in fire-arms and explosions generally, and in the case of atmospheric electricity. In these cases, by noting the interval between the flash and the report, and multiplying the number of seconds in each interval by the number of feet per second in the velocity of sound, the distance can be ascertained with great precision. Thus, if a flash of lightning be seen ten seconds before the thunder which attends it is heard, and the atmosphere be in such condition that the velocity of sound is 1120 feet per second, it is evident that the distance of the cloud in which the electricity is evolved must be 11200 feet.

12. The same sounding body will produce a louder or lower sound, according as the density of the air which surrounds it is increased or diminished. In the experiment already explained, in which the alarum was placed under an exhausted receiver, the sound increased in loudness as more and more air was admitted within the receiver. If the alarum had been placed under a condenser, and highly compressed air collected round it, the sound would be still further increased.

When persons descend to any considerable depth in a diving-bell, the atmosphere around them is compressed by the weight of the column of water above them. In such circumstances a whisper is almost as loud as the common voice in the open air, and when one speaks with the ordinary force it produces an effect so loud as to be painful.

On the summit of lofty mountains, where the barometric column

falls to one-half its usual elevation, and where therefore the air is highly rarefied, sounds are greatly diminished in intensity. Persons who ascend in balloons find it necessary to speak with much greater exertion, and, as would be said, louder, in order to render themselves audible. When Saussure ascended Mont Blanc, he found that the report of a pistol was not louder than a common cracker.

13. Violent winds and other atmospheric agitations affect the transmission of sound. When a strong wind blows from the hearer towards the sounding body, a sound often ceases to be heard which would be distinctly audible in a calm. A tranquil and frosty atmosphere placed over a smooth and level surface is favourable to the transmission of sound. Lieutenant Forster held a conversation with a person on the opposite side of the harbour of Port Bowen, in the third polar expedition of Sir Edward Parry, the distance between the speakers being more than a mile.

It is said that the sound of the cannon at the battle of Waterloo was heard at Dover, and that the cannon in naval engagements in the Channel have been heard in the centre of England.

14. Liquids are also capable of propagating sound. Divers can render themselves audible at the surface of the water; and stones or other objects struck together at the bottom produce a sound audible at the surface.

It appears from the experiments of M. Colladon, made at Geneva, that sounds are transmitted through water to great distances with greater force than through air. A blow struck under the water of the Lake of Geneva was distinctly heard across the whole breadth of the lake, a distance of nine miles.

Solid bodies, such as walls or buildings interposed between the sounding body and the hearer, diminish the loudness of the sound, but do not obstruct it when the sound is made in air; but it appears from the experiments of M. Colladon, that the interposition of such obstacles almost destroys the transmission of sound in water.

15. Solids which possess elasticity have likewise the power of propagating sound. If the end of a beam composed of any solid possessing elasticity be lightly scratched or rubbed, the sound will be distinct to an ear placed at the other end, although the same sound would not be audible to the ear of the person who produces it, and who is contiguous to the place of its origin.

The earth itself conducts sound, so as to render it sensible to the ear when the air fails to do so. It is well known, that the approach of a troop of horse can be heard at a distance by putting the ear to the ground. In volcanic countries, it is said that the rumbling noise which is usually the prognostic of an eruption is

first heard by the beasts of the field, because their ears are generally near the ground, and they then by their agitation and alarm give warning to the inhabitants of the approaching catastrophe. Savage tribes practise this method of ascertaining the approach of persons from a great distance.

16. The velocity with which sound is transmitted through the air varies with its elasticity; and where different strata are rendered differently elastic by the unequal radiation of heat, the agency of electricity, or other causes, the transmission of sound will be irregular. In passing from stratum to stratum differing in elasticity, the speed with which sound is propagated is not only varied, but the force of the intensity of the undulations is diminished by the combined effects of reflection and interference, so that the sound, on reaching the ear, after passing through such varying media, is often very much diminished.

The fact, that distant sounds are more distinctly heard by night than by day, may be in part accounted for by this circumstance, the strata of the atmosphere being during the day exposed to vicissitudes of temperature more varying than during the night.

17. The solids composing the body of an animal are capable of transmitting the sonorous undulations to the organ of hearing, even though the air surrounding that organ be excluded from communicating with the origin of the sound.

Chladni showed that two persons stopping their ears could converse with each other by holding the same stick between their teeth, or by resting their teeth upon the same solid. The same effect was produced when the stick was pressed against the breast or the throat, and other parts of the body.

If a person speak, directing his mouth into a vessel composed of any vibratory substance, such as glass or porcelain, the other stopping his ears, and touching such vessel with a stick held between his teeth, he will hear the words spoken.

The same effect will take place with vessels composed of metal or wood.

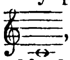
If two persons hold between their teeth the same thread, stopping their ears, they will hear each other speak, provided the thread be stretched tight.

18. Of the various forms of apparatus which have been contrived for the production of musical sounds, with a view to the experimental illustration of their theory, that which is best adapted for this purpose, called a *monochord* or *sonometer* (fig. 2) consists of a string of catgut or wire attached to a fixed point, carried over a pulley, and stretched by a known weight. Under the string is a hollow box or sounding-board, to the frame of which the pulley is attached. The string

rests upon two bridges, one of which is fixed, and the other can be moved with a sliding motion to and fro, so as to vary at pleasure the length of the part of the string included between the two bridges.

A divided scale is placed under them, so that the length of the vibrating part of the string may be regulated at pleasure. By varying the weight, the tension of the string may be increased or diminished in any desired proportion. This may be accomplished with facility by circular weights which are provided for the purpose, and which may be slipped upon the stem of the weight. By means of this apparatus, the relation between the various notes of the musical scale and the rate of vibration by which they are respectively produced have been ascertained.

19. The rate of vibration of a string such as that of the monochord is inversely as its length, other things being the same. Thus, if its length be halved, its rate of vibration is doubled; if its length be diminished or increased in a threefold proportion, its rate of vibration will be increased or diminished in the same proportion; and so forth.

Let the bridges be placed at a distance from each other as great as the apparatus admits, and let the weight which stretches the string be so adjusted, that the note produced by vibrating the string shall correspond with any proposed note of the musical scale; such, for example, as , the low C of the treble clef. This being done, let the movable bridge be moved towards the fixed bridge, continually sounding the string until it produces the octave above the note first sounded, that is, until it produces the middle C  of the treble.

If the length of the string be now ascertained by reference to the scale of the monochord, it will be found to be precisely one-half its original length

20. Hence it follows, that the same string will sound an octave higher if the length is halved. But the rate of vibration will be doubled when the length of the string is halved. Hence it follows, that two sounds, one of which is an octave higher than the other, will be produced by vibrations, the rate of which will be in the proportion of 2 to 1; and, consequently, the length of the undulation producing the lower note will be double that of the undulation producing the higher note.

By like experiments it is shown that the more frequent the coincident vibrations are the more perfect is the harmony, and the less frequent they are the more discordant are the notes.

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